AD-A215 854

DTIC
ELECTE
DEC 29 1989
S   D
B

A CASE STUDY OF THE WATER SUPPLY SYSTEM
AT NELLIS AIR FORCE BASE
USING COMPUTER SIMULATION

THESIS

Stephen D. Grumbach
Captain, USAF

AFIT/GEM/ENS/89S-9

DEPARTMENT OF THE AIR FORCE

AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

89 12 28 068

②

A CASE STUDY OF THE WATER SUPPLY SYSTEM
AT NELLIS AIR FORCE BASE
USING COMPUTER SIMULATION

THESIS

Stephen D. Grumbach
Captain, USAF

AFIT/GEM/ENS/89S-9

DTIC
S ELECTE D
DEC 29 1989
B

AFIT/GEM/ENS/89S-9

A CASE STUDY OF THE WATER SUPPLY SYSTEM

AT NELLIS AIR FORCE BASE

USING COMPUTER SIMULATION

THESIS

Presented to the Faculty of the

School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Engineering Management

Stephen D. Grumbach

Captain, USAF

1989

Acknowledgements

The production of this thesis has involved the help of many people to whom I am very grateful. Their contributions have allowed me the opportunity to experience firsthand the research process and attempt to reach significant conclusions.

I am deeply indebted to my thesis advisor Lt Col Thomas Schuppe, whose patience and guidance was always there when I needed it. His optimistic support and scholarly advice simplified the thesis production process and improved the quality of this study.

There are a number of people at Nellis AFB who also aided this research above and beyond what was required. Mr Robert Dorsey provided needed contractual information on the Las Vegas valley system. Mr Robert Rodowick and the Nellis water shop provided solid information on the actual system hardware and performance.

Finally a friend of mine at Nellis, 1Lt F. Susan Keller, not only provided me with needed data but also gave much needed support to move ahead and complete this work.

Table of Contents

List of Figures

List of Tables

Abstract

The water supply system of a military installation is an integral part of the utility infrastructure and critical to the mission of the base. The system must be prepared to handle domestic, industrial, fire-fighting and chemical decontamination requirements in a reliable manner.

The purpose of this study was to examine, through the use of standard techniques and computer modeling, the current and future supplies and demands of the water utility system at Nellis AFB, Las Vegas, Nevada. The desired macroscopic perspective suggested the use of accurate statistical and simulation techniques. A general approach was taken so that the procedure is applicable to other Air Force water systems as well.

Based on historical data, current operating conditions and projected demands, the Nellis water system is at a critical point if the base management is concerned about safety as well as future expansion. Current ability to fight a fire for extended periods is suspect. Current and future storage needs do not fit Air Force guidance and are far below civilian requirements. Future construction plans will significantly increase demands on the system. To account for these increased demands, supplies must be

increased as well. Unfortunately, there are few new sources
and the costs will increase dramatically.

The simulation model provided a tool for the analysis
of water systems and could be useful in future utility
analysis.

A CASE STUDY OF THE WATER SUPPLY SYSTEM

AT NELLIS AIR FORCE BASE

USING COMPUTER SIMULATION

I. Introduction

Background

During the past several years, the United States has
noted the alarming deterioration of its basic infrastructure
such as utility systems, transportation facilities and water
supplies. There are many parallels between military and
civilian facilities. Thus, discussions on infrastructure
problems apply equally well to both the Air Force
installation and the civilian community. Infrastructure is
defined by the National Council of Public Works Improvement
as "the physical framework that supports and sustains
virtually all economic activity" (Thornton, 1987:580). This
definition implies a very important but often ignored
dependency that society has on its infrastructure and its
development. For too long the nation has ignored its basic
framework, one estimate by the Associated General
Contractors (AGC) in 1987 placed the cost to completely
repair the nation's infrastructure at 3 trillion dollars
(Thornton, 1987:580).

In military terms, the success of the mission is directly related to the quality and effectiveness of these systems. Major General George E. Ellis, head of Engineering and Services, noted this in his statement:

> Given the important war-fighting contribution of our basing support systems, we need to press for a major reinvestment in their facility infrastructure. Too many of our critical war-fighting facilities are over 40 years old. Many of them have outlived their peacetime and wartime usefulness. Not only are our basing systems old, they are also insufficient. (Ellis, 1986:9)

Water has always been a particularly important resource because of its domestic, industrial and fire-fighting uses. In addition, the military has special requirements for water such as chemical warfare decontamination. Water, however, like any other resource must be managed properly to ensure its availability and effective use. Henry J. Graeser, director of water utilities in Dallas, sets the tone of his narrative on water supply in American Water Works Association Journal with the following excerpt:

> Just suppose that through an act of sabotage or a sudden assault, New York City or any other great city were to be deprived of its entire water supply. The results would not be as instantly horrifying as the explosion of a hydrogen bomb, but over a short period of time, the disaster would be almost as demoralizing...Defenses against man's most deadly enemies, the disease-causing germs, would be dangerously lowered. And the fact that not a toilet in the whole city would flush would open up another fatal breach in the walls of public health....Thirst, malnutrition, and disease would not be the only dangers menacing the population. The fire department would be left without weapons to fight any but the most minor

2

conflagrations. Urban life, and this is now the
life of a majority of Americans, is peculiarly
dependent upon water. Without it, cities simply
could not exist. (Graeser, 1985:14)

Undoubtedly, this view would be taken by many people as

overly-exaggerated and biased except for all but a large-

scale catastrophe. The day-to-day depletion of water supply

sources is not nearly so dramatic but is in fact becoming a

health and development inhibiting problem. While generally

considered a renewable resource, water does in fact have a

limited supply.

Supplies of water vary greatly from one geographic
region of the country to another. Seasonal
distribution, as well as the total amount of
rainfall, differs from place to place, leading to
variations in the cost of making sufficient
quantities of water available at a given place and
time... The time has come in some locations and is
approaching in others, that increasing use of
water is depleting easily acquired supplies.
(Campbell, 1985:53)

Given that some areas do face a shortage of water

versus the required demand, officials must then decide who

gets how much.

Who owns the water hole? The answer: everybody
and nobody... Does a fish have a better claim to
water than a farmer, a megalopolis, or a high-tech
industry? Ridiculous as it seems, such are the
ingredients of disagreements about allocating
water. (IMS, 1985:33)

Within a water district or region, an Air Force

installation represents another demand competing for that

resource. The particular installation needs to monitor and

3

manage its demand so that sufficient water supplies are available and cost effective. Installations located in arid, hot areas with low water supply must be particularly conscientious.

The Air Force owns an inventory of water storage tanks capable of holding 5,030,561,000 gallons and 11,171 miles of water transmission line. These alone have current values of $144,067,000 and $345,799,000 respectively (Mckinney, 1989). This does not include the cost of pumps, facilities, meters or even the ongoing water contracts with civilian utility companies. The task of operating and managing the water supply and distribution system for an Air Force installation is part of the mission of Base Civil Engineering.

This task is divided into two parts: 1) the engineering and monitoring and 2) the operation and maintenance. The engineering and monitoring, typically performed by an assigned engineer in Technical Design, consists of designing large-scale construction, monitoring system performance and initiating water conservation efforts. The operations and maintenance is done by the Water & Waste shop and the Plumbing shop. They repair small breaks, perform routine maintenance and physically monitor tank levels, well outputs etc.. (see Figure 1)

Nellis Air Force Base is an important, preeminent base in Tactical Air Command. Located in the northeastern corner

4

of Las Vegas, Nevada, it is home to the Tactical Fighter
Weapons School, the USAF Thunderbirds, Red Flag, Red Horse
and a handful of other organizations. The desert southwest
location is also very hot and dry: it receives less than
3.5 inches of rain a year and temperatures can reach 115° F
in the summer. While the abundance of sunshine provides
many hours for flight training, it is hard on a water supply
system. As such, the Nellis golf course uses an average of
one million gallons of water a day during the summer.
Nellis AFB has expanded over the past two decades, and its
water demand has grown dramatically as well. Unfortunately,
because of physical and contractual restraints, its water
supply has not grown correspondingly with demand. According
to retired Nellis superintendent Ray O'Dell and other
experts, the supply shortage has reached a critical stage
where it could affect future growth/development or have
catastrophic effects during an emergency (O'Dell, 1989).

Problem Statement

The purpose of this research is to examine, through the
use of standard techniques and computer modeling, the
current and future supplies and demands of the water utility
system at Nellis AFB, Las Vegas, Nevada. Because the
domestic, industrial and fire-fighting capabilities of water
are essential to an installation, their requirements must be

5

CIVIL ENGINEERING ORGANIZATION CHART
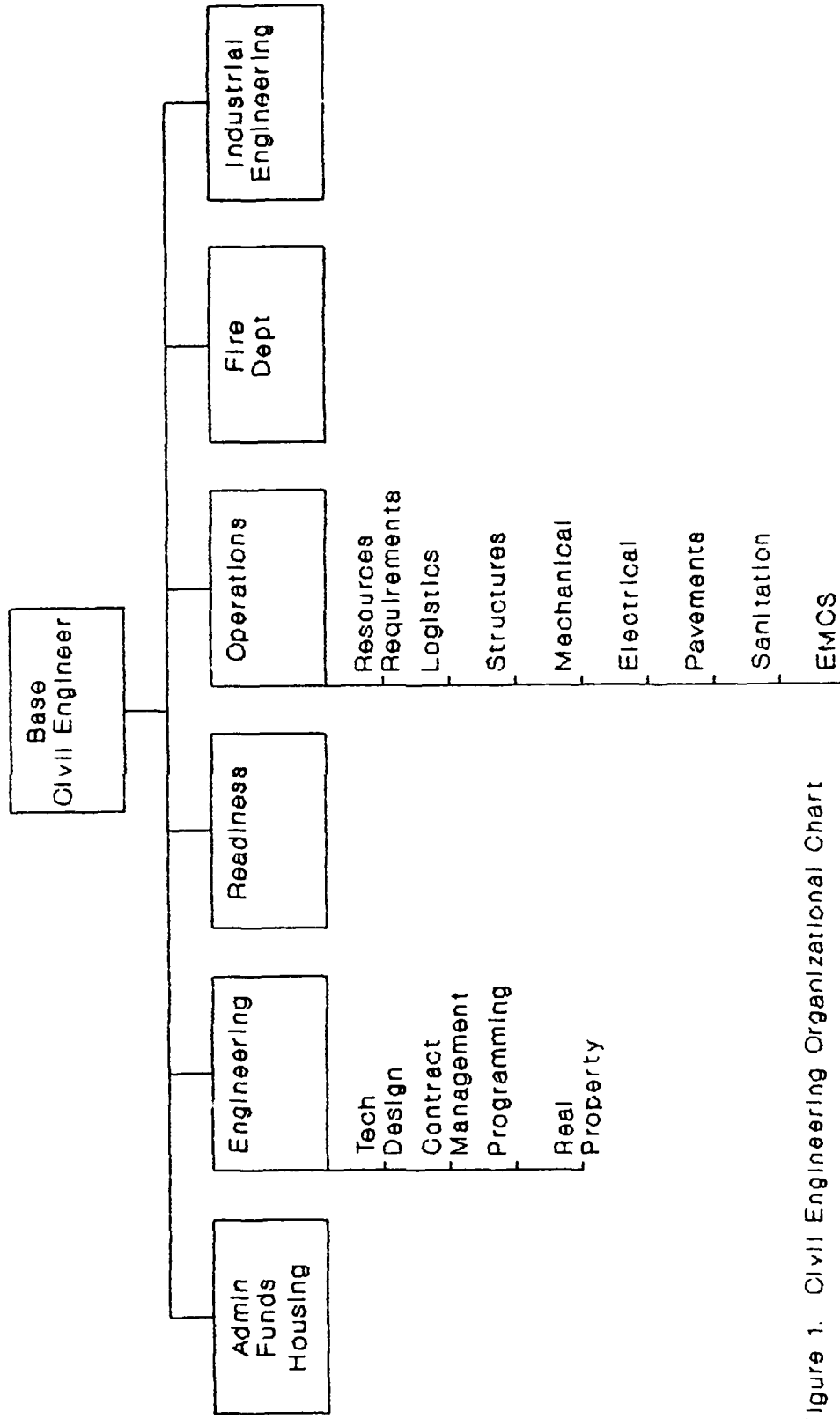
Figure 1. Civil Engineering Organizational Chart

continually evaluated to ensure sufficient capacity. The importance and cost involved with large water systems suggested the use of accurate statistical and simulation techniques. A general approach will be taken so that the procedure could be applicable to other Air Force water systems as well.

Research Objectives

The research is directed towards meeting two specific objectives in order to increase the Civil Engineering planner's base of knowledge and decision-making tools concerning water distribution systems.

Objective 1. Research objective one is to understand and evaluate analytically the water distribution system at Nellis AFB. The following investigative questions are aimed at providing the information needed to achieve this objective.

1a. What are the capacities, operating conditions and major components of the water supply system?

1b. What do standard analytical techniques provide as to the present and future demands on the system?

1c. Using military and civilian design requirements, what is the calculated amount of storage required?

1d. What is the condition of current water supplies?

Objective 2. Research objective two is to develop a simulation model of the water distribution system at

7

Nellis AFB.   The following investigative questions are

aimed at providing the information needed to achieve

this objective.

2a.   What are the components, processes, parameters and
level of detail that need to be modeled?

2b.   Is a higher order simulation language appropriate
for this application and can it accurately model the system?

2c.   What are the appropriate probability distributions
for the water supply sources and base demands?

2d.   How should the model be validated?

2e.   What is the effect of impressing a fire loading
upon the system?

2f.   What are the required supplies and storage
required for future demands?

Scope and Limitations

This research has been limited to an analysis of the

water system at Nellis AFB in terms of sources, storage and

demands.   Specifically considered are: 1) water wells and

their associated interconnections, 2) water allocations from

the Colorado River Commission, 3) water storage capacities

and their interactions, 4) performance of the system in

delivering water as demanded, 5) the reasonably anticipated

demand of a fire.

There are many variables involved in a real-life Air

Force installation that affect the way engineers, planners

and commanders make decisions.   To incorporate them (even if

they could all be identified) into a model would be

impossible. Therefore, several assumptions/constraints have also been applied in order to reflect the real world situation.

The geographic scope covers all of Nellis proper including the main base, Area II and Manch Manor. Remote sites such as Indian Springs will be excluded.

Because the research takes a macroscopic view of the problem, a significant level of detail will be excluded or assumed. The purpose here is to determine if the overall supply to the base is adequate. A lack of supply to a particular point in the service is generally a problem with existing hardware and can be corrected by simple engineering analysis. The overall lack of supply poses a much larger, long-range management problem because the Air Force Civil Engineering unit must negotiate with external organizations. The service distribution grids will therefore be viewed as large, inclusive demand points. The flowrate and pressure at a particular point will be assumed adequate if the storage tanks contain water or the instantaneous supply rate is greater than the instantaneous demand. This assumption is very critical and could be challenged because of the existing water in the service lines. In general though for gravity fed systems, an empty tank will not keep the system pressurized and the standing water (in the pipes) would still be unusable.

The operating conditions at the time of this study will be considered constant for the foreseeable future. Hardware such as pumps, wells, tanks, and lines will be configured and operating at current conditions. The loss of a well or the loss of a large part of the base mission (demand), for example, does not seem apparent at this time. Because such occurrences are not readily predictable, they will not be included.

Another possible action that could deviate the results of these findings from reality would be severe water conservation or rationing. Should the installation take this course of action beforehand, the damaging effects of an emergency would obviously be mitigated. Because the total effect of such conservation is unknown, it will not be included.

Other emergency techniques such as using water trucks or other mobile, non-permanent water storage tanks will not be taken into account as well. The base water system, for maximum flexibility and emergency potential, should be designed long-term to handle these loads.

The sources of the water, in-house wells and the Colorado River Commission (CRC) form the input boundary to the system. Everything that occurs prior to the waters arrival at this point is external. For example, aquifer

processes taking place in the ground as well as water

treatment by the CRC is beyond the scope of this research.

II.   Review of the Literature

Overview

This section provides the current information regarding the topic of this research. The material is arranged in a logical sequence to bring the problem into perspective as follows: an overview of the Nellis water system, the Nellis Water System Components, Air Force and civilian storage requirements, a general discussion of regional water law, and possible simulation languages.

Overview of the Nellis Water System

The following overview was taken from the URS water study (Hydraulic Analysis of the Nellis AFB Water Distribution System) done at Nellis from 1985-1986 and personal observations. The Nellis AFB water supply system is complex and dynamic: three well sources, one interconnection with the Colorado River Commission (CRC) supply, nine storage facilities, and seven pump stations. Figure 2 shows a schematic view of the major system components. All components of the system are strongly interrelated, each influencing the other during operation. The system is a combination of both manual and automatic features with the water supply from the wells and automatic control of the CRC supply. The booster pumps are controlled
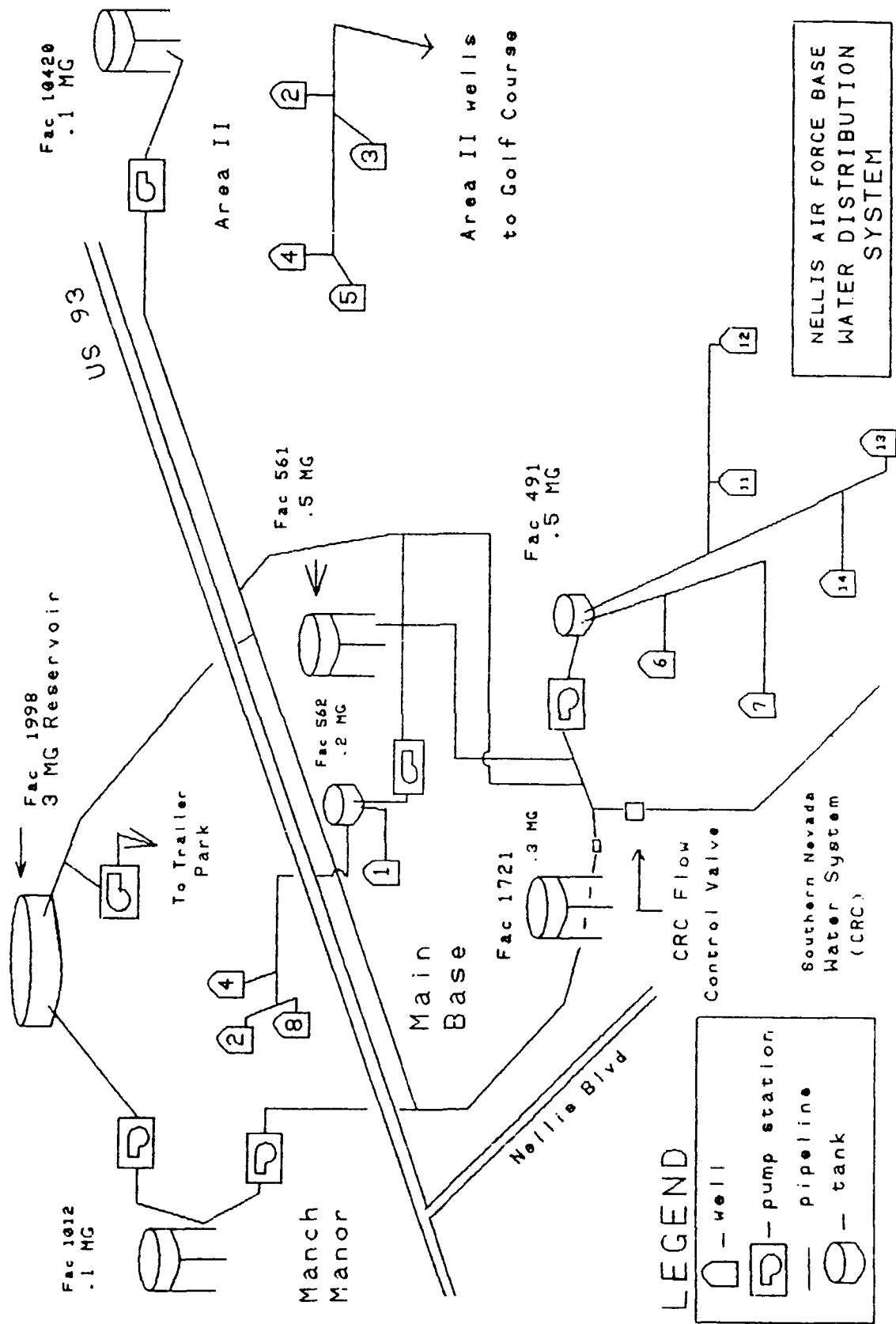
Figure 2. Nellis Water System

13

automatically and are dependent on either storage tank levels or pressure. Therefore when the water supply is sufficient, the system operates in a relatively satisfactory manner. The majority of the system is one pressure zone with three small higher pressure zones. The three high pressure zones are Manch Manor, Area II and Area III. All water is delivered to the main base pressure zone and is then pumped to higher elevations as needed. The system currently draws some tanks dry during peak demands.

Nellis AFB receives its water from two sources: 1) the CRC through the Southern Nevada Water System (SNWS) and 2) water wells operated by Nellis AFB. Both sources have maximum established limits for annual usage and peak flow rates. The use of the different sources varies seasonally throughout the year. During the winter months nearly 100% of the water is supplied by the SNWS. This is an operational decision made by Nellis to relieve the wells for a period of time. During the summer months the wells are used to supplement the SNWS water.

The SNWS enforces a water curtailment from 1000 to 2200 hours during the months of June through September. During this time the purchase of water from SNWS must be requested and a surcharge is assessed. Typically, Nellis requests water during this time period on a number of occasions when demand exceeds their supply from wells and storage tanks.

14

In addition to Nellis AFB requiring and obtaining water during curtailment periods, Nellis AFB has been allowed, in the past summers to exceed its flowrate withdrawal of 6 cubic feet per second (cfs) from SNWS. This occurs through a temporary formal agreement at the discretion of the other users and is renewed annually. Because of this leniency by SNWS, Nellis AFB has not felt the full impact of its apparent water problem.

Nellis Water System Components

Wells. The existing wells of Nellis AFB are divided by location into three distinct groups; the desert wells, the base wells, and Area II wells. The water from these locations is pumped from each well to storage tanks and is then pumped into the system through booster pumps. Area II wells have not been used in recent years, however they are currently being brought on-line for golf course irrigation purposes. All well pumps operate in a manual on/off mode.

Desert Wells. The desert wells are located approximately 5 1/2 miles west of the main base. Three wells are located at this point; numbers 2, 4, and 8. The water from each well is delivered to the main base at facility 562 (a .2 mg storage tank) and then pumped through booster pumps, facility 563, into the system. Well number 1, located on the main base, also pumps water into facility

562 and is included within this section of the desert wells because of its intertie with facilities 562 and 563.

Well 1. This well is located on the main base at facilities 562 and 563. It was drilled in 1941 and is 784 feet deep with a 16" casing installed. No well capacity test was performed. Nellis AFB currently has water rights of 0.67 cfs (300 gallons per minute, gpm) for this well. Historical production rates from this well range from 200 to 250 gpm.

Well 2. Well 2 is located 5 1/2 miles west of the base. It was drilled in 1952 to a depth of 300 feet with a 20" casing installed. No well capacity test was performed. Nellis AFB currently has water rights of .8 cfs (359 gpm) and 431 acre-feet (af) annually, for this well. Historical production rates for this well have generally been around 610 gpm.

Well 4. Well 4 is located 5 1/2 miles west of the base. It was drilled in 1943 to a depth of 423 feet with a 12" casing installed. No well capacity test was performed during development. The well was rehabilitated in 1986. Nellis AFB currently has water rights of .5 cfs (224 gpm) and 362 af annually, for this well. Historical production delivery rate to facility 562 is estimated to be 430 gpm.

Well 8. Well 8 is located 5 1/2 miles west of the base. It was drilled in 1959 to a depth of 900 feet with a

16

12" casing installed. Two water rights have been acquired
for this well, one at .6 cfs and a second at .76 cfs for a
total of 1.36 cfs (610 gpm) and 852.6 af annually. The
historical delivery rate is estimated to be around 500 gpm.

Base Wells. This group of wells is located at the
south end of the main base, not closely grouped together.
Base well water is delivered to facility 490 and 491 for
chlorination and increased pressure if not used for golf
course irrigation. The piping is such that wells 12 and 13
can be dedicated solely to supplying water to the golf
course or pumping into facility 491 (a .5 mg tank) and then
through facility 490 into the base system.

Well 6. This well was drilled in 1951 to a depth
of 1000 feet and had a 12" casing installed. The well log
includes the remark that the well yielded 650 gpm with a
draw down of 220 feet. The static water level was 58 feet
at the time of the installation. Nellis AFB currently has
0.55 cfs (247 gpm) and 184.2 af per annum water rights for
this well. The historic production delivery rate to
facility 491 is estimated to be 325 to 360 gpm.

Well 7. This well was drilled in 1952 to a depth
of 760 feet and had a 12" casing installed. The well log
includes the remark that the well yielded 320 gpm with a
draw down of 220 feet. The well was rehabilitated in 1985
resulting in increased capacity. Nellis AFB currently has

17

0.55 cfs (247 gpm) and water rights included under well 6. The historic production delivery rate to facility 491 is estimated to 400 to 430 gpm.

Well 11. This well was drilled in 1962 to a depth of 802 feet and had a 12" casing installed. The well log information includes a draw down curve developed during well tests. The specific yield from the well is approximately 3.1 gallon per foot of draw down. From reviewing the original well report it appears that the well was developed for a 350 gpm flow. The historic production delivery rate to facility 491 is approximately 300 to 400 gpm.

Well 12. This well was drilled in 1962 to a depth of 1000 feet and had a 12" casing installed. The well log information includes draw down information developed during well tests. The specific yield is approximately 5.7 gallons per foot of draw down. This well currently serves the golf course and has been estimated to be 500 to 590 gpm.

Well 13. This well was drilled in 1962 to a depth of 694 feet and had a 14" casing installed. The well log information includes draw down curve information developed during well tests. The specific yield is approximately 4 gallons per foot of draw down. Some problem with sanding was noted in the well logs. The well has also gone dry during use in recent years. This well currently serves the

18

golf course. The historic production delivery rate to the golf course has been around 375 to 425 gpm.

Well 14. This well was drilled in 1962 to a depth of 650 feet and had a 14" casing installed. The well log information includes draw down curve information developed during well tests. The specific yield is approximately 1.75 gallons per foot of draw down. Some problem with sanding was noted at a 445 gpm flow during the well development. No sanding problems are currently encountered. The historic production delivery rate to facility 491 is estimated to be approximately 225 to 250 gpm.

Area II Wells. The Area II wells consist of four wells located south of U.S. 93 and east of the main base area clustered close together. Nellis AFB took over the operation of these wells in 1977. These wells were piped so that they pump into .05 mg wet well (facility 10107) and feed Area II. In recent years the wells have experienced some arsenic in the water, therefore these wells taken off line. In 1986 Nellis AFB installed a transmission line from these wells to the golf course, allowing this water to be used for irrigation.

Well 2. The well was drilled in 1952 to a depth of 1434 feet and had a 10" casing installed. The well log noted that 197 gpm was pumped with a draw down of 371 feet.

The historic production delivery rate to facility 10107 is estimated to be 125 to 140 gpm.

Well 3. The well was drilled in 1953 to a depth of 1247 feet and had a 14" casing installed. The well log noted, "245 gallons per minute with a draw down of 319 feet, 98 hour test. Water level when first started was 131 feet." In 1982 a new pump was installed at this well. The historic production delivery rate to facility 10107 has been approximately 130 to 250 gpm.

Well 4. The well was drilled in 1953 to a depth of 1036 feet and had a 14" casing installed. The well log noted, "295 gallons per minute with a draw down of 318 feet, 96 hour test. Water level when first started test was 132 feet." The historic production delivery rate to facility 10107 has been approximately 160 to 195 gpm.

Well 5. No information was found on this well from well logs. The historic production delivery rate to facility 10107 is approximately 110 to 125 gpm.

The water rights are obtained from the Department of Water Resources, which included rights to eight of the active wells. Some of the historic information came from reports filled out during well drilling. These forms are entitled Well Log and Report to the State Engineer of Nevada (URS, 1985:13).

Storage. Nellis AFB currently maintains nine storage
facilities. Of these nine, five are actively connected to
the system and four are wet well types that require
interaction with booster pumps to pressurize the system.
The total Nellis AFB storage volume currently on-line is 5
million gallons (mg), 4 mg of that storage is available on
demand without the need of booster pumps (URS, 1985:15).

Facility 1012. This storage tank is located on the
South edge of Manch Manor on Craig Road. It is a 0.1 mg
elevated tank built in approximately 1960. The tank water
level fluctuates significantly and during peak demand the
tank goes dry. The overflow elevation is approximately 2013
feet, 26 feet higher than the main base pressure zone. The
water is boosted in pressure by either one or both sets of
pressure pumps, one set located directly under the tank, the
other set located at the northern end of Manch Manor.

Facility 1999. This 3 mg storage tank is located at
the end of Range Road. The tank floats on the main base
pressure system, that is water is neither pumped to or from
the tank as it serves the main base. The overflow elevation
is 1987 feet. The tank does not have an altitude valve,
allowing it to overflow in the rare instant that the main
base system pressure rises to the top of tank 561 (1987
feet). The tank was built in 1983 as part of a major system

upgrade project. On days of peak demand the tank will drain to half capacity.

Facility 561. This 0.5 mg elevated storage tank is located in the center of the main base. Its upper water surface level is 1987 feet when the base is receiving water from the SNWS. At other times it is possible to boost the water up to 1991 feet. The water surface level in this tank regulates the automatic operation of facility 563 booster pumps and the supply from SNWS. The tank was built in approximately 1940.

Facility 562. This 0.2 mg storage facility operates in partnership with the supply from the desert wells and booster pump facility 563. The wells pump into this holding tank with booster pumps then the water is pumped into the system. The wells operate manual on/off. The booster pumps are automatic dependent on the water surface level of tank 561.

Facility 1721. This 0.3 mg elevated tank is located at the south end of Wherry housing and operates on the system without a booster pump partnership. The overflow elevation is 1977, 10 feet lower than the main base pressure. The feed line into the tank is pressured from the main base, an altitude valve keeps the tank from overflowing. Due to its low elevation the water stored within this tank is generally only used by Manch Manor.

Facility 491. This facility operates in partnership with the water supply from the base wells and booster pump facility 490. The wells pump into the .5 mg holding tank with the booster pumps then the water is pumped into the system. The wells operate manual on/off. The booster pumps can be operated automatically, dependent on the water surface level of the tank, however they are currently operated manually.

Facility 10107. The storage volume of this facility, 0.05 mg, is minor enough to be classified as insignificant in terms of system storage. The purpose of the facility was to act as a settling tank for the water from the Area II wells. From this tank, the water was pumped through booster pumps into Area II. Due to the detection of arsenic in Area II well water, the wells are now pumping directly to the golf course and bypassing this facility.

Facility 10113. This facility is the intertie (connection) between the main base pressure zone and the higher Area II pressure zone. The overflow elevation in the 0.3 mg wet well holding tank is approximately 1987 feet. This facility operates in partnership with the water supply from the base and booster pump. The base water flows into the holding tank and then the booster pumps pressurizes the water into the system. The booster pumps are automatic depending on the water surface level of the 10420 tank.

Facility 10420. This facility is an elevated tank

located in the restricted area of Area II. The overflow

elevation is 2209 feet. The tank serves to supply peak

demand to Area II without causing the 10113 pumps to

frequently cycle on and off. The tank has a capacity of 0.1

mg (URS, 1985:13).

Colorado River Commission

Appropriation of stream flow on the Colorado River has

been interpreted according to legal documents which make up

the "Law of the River" (URS, 1985:29). Some of the major

legal actions concerning the Colorado River are summarized

below.

The Colorado River Compact of 1922 was set up to

provide for the diversion of the waters from the Colorado

River system. It established a preference for agriculture

and domestic uses over power generation. The boulder Canyon

Project Act of 1928 authorized the construction of Hoover

Dam and powerplant. It also authorized the States of

Arizona, California and Nevada to enter into an agreement

whereby Nevada received 0.3 million acre feet per year

(Edwards, 1989). To oversee the development and

distribution of Nevada's apportionment, the Colorado River

Commission of Nevada was created as a state agency in 1935

(URS, 1985:20).

24

By the 1950's it became clear that the rapid population growth in Las Vegas would require an additional water source to augment the local groundwater supply. The Southern Nevada Water System (SNWS) was formed as the means for diverting Colorado River water into the Las Vegas Valley. In 1968 the initial phase of the project was authorized and was completed in 1971. This first phase was capable of delivering a maximum of 132,200 acre-feet per year. Construction of the second phase was begun in 1978 and increased the capacity to 300,000 acre-feet annually (Edwards, 1989).

In 1978 the Federal government entered into an agreement with the State of Nevada acting through the Division of Colorado River Resources for the allocation of 4,000 af annually for Nellis AFB, "provided that if additional water is available to the Division and, if so scheduled by the Government, the Division may deliver additional quantities of water to Government in any one year (URS, 1985:20)." Also established at that time was a maximum flowrate of 6 cfs and system head delivery elevation between 1987 and 1975 feet.

Storage Requirements

The overall objective of any water distribution system is to deliver sufficient quantity and quality of water as

25

required. In order to produce sufficient quantity at all points in the system, adequate quantities of water must be produced at the water treatment plant, pressure levels within the distribution system must be high enough to provide suitable service to the user and transmission mains must have sufficient capacity to carry the required flows (Upmeyer, 1978:50). It is usually uneconomical to operate facilities with sufficient capacity to supply the instantaneous maximum demand. Therefore, storage is necessary to counter the varying loads and peak flow demands.

Civilian Requirements. In general, storage facilities serve five purposes.

1) Peak Demand Rates - the storage volume required to meet the hour-to-hour variations of a maximum day. Using past demand curves this amount can be calculated by finding the maximum total amount required by the users in a 24 hour period minus the water produced during this period as well. It should be pointed out that future maximum demands should be considered as well so that newly constructed tanks do not quickly become inadequate.

2) Fire Fighting Requirements. Storage requirements must also be evaluated for possible fire fighting contingencies based on the size and types of buildings within a distribution area. Several organizations such as

26

the Insurance Services Office (ISO), the National Fire

Protection Association (NFPA) and even the Air Force have

guidelines for fire-fighting requirements.

3) Provide operational flexibility

4) Provide pressure and flow equalization

5) Provide system reliability. The amount of storage

available for a sustained period of time with the loss of

primary supplies.

The first two categories are primarily quantitative

while the latter three are more characteristic of the

management and operation of the system (Upmeyer, 1978:50).

Military Requirements. In addition, design guidance is

provided by military regulation AFM 88-10.

> a. All military installations. In general,
> total storage capacity, including elevated and
> ground storage, will be provided in an amount not
> less than the greatest of the following items
> (para. 3-2).
>
> Item 1: Fifty percent of the average total daily
> domestic requirements plus all industrial
> requirements. This will provide minimum
> operational storage needed to balance average
> daily peak demands on the system and to provide an
> emergency supply to accommodate essential water
> needs during minor supply outages of up to a one-
> day duration. For the purposes of this item,
> essential water needs do not include the fire
> demand.
>
> Item 2: The fire demand. The fire demand is the
> required fire flow needed to fight a fire in the
> facility (including water required to support fire
> suppression systems) which constitutes the largest
> requirement for any facility served by the water
> supply system (calculated IAW TM 5-813-6/AFM 88-
> 10, Vol. 6); plus 50 percent of the average

27

domestic demand rate plus any industrial or other
demand that cannot be reduced during a fire
period. This amount will be reduced by the amount
of water available under emergency conditions
during the period of the fire (TM 5-813-1/AFM 88-
10, Vol. 1).

Note

The fire demand quantity must be maintained in
storage for fire protection at all times except
following a fire fighting operation when the fire
demand quantity would be depleted. It is
recognized that during daily periods of peak
consumption due to seasonal demands, the amount of
water in storage will be less than full storage
capacity; however, conservation methods will be
instituted to prevent drawdown of water to storage
below the fire demand quantity. Water storage
greater than the amount determined by the largest
of Items 1, 2, or 3 may be required because of
appropriate adjustments for emergency however,
this must be substantiated by actual data on a
repeated annual basis documenting the low storage
levels occurring during normal peak demand.

Item 3: The sum of Items 1 and 2 above, that is,
the sum of fifty percent of the average total
daily domestic requirements, all industrial
requirements for an average day which cannot be
shut off during emergency conditions, and the
required fire demand. The sum of the above items
will be reduced by the amount of water available
in 24 hours under emergency conditions. This will
provide maximum storage where emergency water
supply is a minimum over a 24-hour period or a
supply main outage would significantly affect
overall supply conditions. The most economical
alternative for meeting the water storage
requirements will be selected in all cases.
Installation of additional water pumping
facilities, additional water supply connections,
drilling additional wells or other modifications
to the water system which will be more cost
effective than increasing storage capacity will be
developed. (AFM 88-10, 1985:2)

Fire Flow Requirements

The water fl..w requirements for fighting fires of various sizes must be included as part of any design or study of water supply and distribution system. The primary factors of fire flow requirements are 1) the building sizes, 2) types of construction materials (wood vs. non-flammable) and 3) the inclusion of sprinkler systems. Air Force manual 88-10, Chapter 6 gives specific guidance as to what criteria should be applied. "Overall water supply system design at any particular installation will be based upon meeting the predominating largest demand under variable conditions for the maximum prevailing fire-flow requirement" (AFM 88-10, Chapter 6).

Simply put, this means the largest single fire requirement should be used to size the necessary flow. The manual covers several different types of major facilities: housing, hospitals, special administrative facilities, large depots, aircraft hangars and specialty installations.

The governing type of building would appear to be the special facility of the commercial, community, industrial, and technical buildings. The requirements are as shown in Table I.

Two facilities at Nellis could qualify for these largest groupings. They are shown in Table II. Therefore, the maximum requirement that could be expected would be a

29

Table I. Facility Fireflow Requirements

Table V.   Fire-Flow Requirements (gpm) for Hose
Streams* (Commercial, Community, Industrial, and
Technical Buildings)

Area Sq Ft	Hours	Fire-Resistive Unprotected	Ordinary WoodFrame
Under 5,000	2	1,000	1,000
5,001-10,000	2	1,000	1,250
10,001-25,000	3	1,000	1,500
25,001-50,000	3	1,500	2,500

* In addition to any requirements for automatic
sprinklers (USAF, AFM 88-10, Chptr 6., 4)

stream of 2,500 gpm for 4 hours. Generally, the manual

appears to have a maximum duration of 4 hours for any type

of building and a maximum fireflow size of 4000 gpm for

wooden hangars (AFM 88-10, Chapter 6).

Table II. Maximum Facility Requirement

No.	Description	Square Footage
20	Consolidated Base Personnel Office	56,000

Western Water Law

The current problems of many large water users in the

West - guaranteed supplies, potential for expansion, and

environmental problems can be traced to the history of the

American West and its development. In order to understand
the predicament of water users such as Nellis AFB, it may be
helpful to briefly review the evolution of western water law
and its eastern counterpart.

Riparian Right. The Riparian Rights doctrine was
originally developed in England in the early 1800's and was
the system adopted for use by the Eastern United States.
Early English Common law provided that a landowner owned
everything above and below his property from the center of
the earth to the sky (Campbell, 1985:54). In order to
provide sufficient quantities of water to all consumers,
early decisions in the 1800's changed this view to give the
government authority to control the private use of water.
Then in 1843 a decision was made that became known as the
English Common Law Rule and evolved into the Riparian
Doctrine. It basically says:

> Those owning land adjacent to flowing stream
> are entitled to use the water that past their
> property. But this right does not include
> permission to divert portions of the water in the
> stream of the action would lead to reduced flow to
> downstream owners to an extent great enough to
> deprive them of water needed from the stream.
> (Campbell, 1985:54)

In both England and the United States this system was
created during conditions of abundant water; attempts to
determine an accurate, equal distribution were never
necessary.

Thus, Riparian owners effectively share the watercourse and are required to respect the rights of other landowners to use water in the future. In this view, water is an integral part of the natural ecosystem and a national resource as well. In addition, water increased the property value and added aesthetic beauty to the parcels of land connected to it (Wilkinson, 1986:34).

Riparian is derived from the Latin word meaning bank of the river (Campbell, 1985:54). Since its inception, the Riparian doctrine has always required that the land be in contact with the stream or body of water, since proximity without contact is not sufficient.

The Prior Appropriation Doctrine. The core of Western water law, the prior appropriation doctrine, was created to meet the demands of miners during the California Gold Rush. Water was essential to the miners operation whether it was for washing away gravel in pans or sluice gates, using high-powered hydraulic hoses or just simple domestic needs (Wilkinson, 1986:34). The Riparian notion that water was in itself a treasure that should be available to all was nonsense to the miners. They needed a simple, easy-to-interpret law that would allow them to get on with their business. Unless large quantities of water could be assured, mining and society itself could not proceed.

32

The ownership of water rights developed exactly the
same as the custom of staking out a land claim. The first
miner to claim an area was accorded the right to work it.
In like fashion, the order of precedence also determined who
had "absolute right of priority" (Campbell, 1985:54). In
other words, ownership of the water is determined by
seniority. First users are guaranteed a supply of water.
Junior users may be cut off in times of shortage according
to their priority.

> There is no sharing of water, there is no
> need to preserve water in a watercourse. A stream
> or lake can be drained low or dried up entirely,
> as has occurred with hundreds of western rivers
> and streams, even the lower Colorado. (Wilkinson,
> 1986:36)

Several court decisions at the time supported this
philosophy on the grounds that "courts are bound to take
notice of the political and social conditions of the country
which they judicially rule (Wilkinson, 1986:36)." The
precept felt by the government and populace at the time was
that water decisions are best made by the water users
themselves.

Eventually, farmers and ranchers were the next wave of
settlement to take place. They too, realized that water was
a high value commodity for their activity. Because of low
rainfall in the west, water had to be taken out of main
watercourses and used to irrigate fields. The appropriation

law worked well for farmers who depended on water for irrigation and gave them legal rights. The Federal government a¹so desired to hasten settlement of the west through large water projects specifically for irrigation purposes (Wilkinson, 1986:36).

Computer Simulation Programs

Typical water simulation models are used by engineers and are mainly concerned with the system hardware. Pipe diameters, pressure heads and valve operations are some of the detailed work with which they are concerned.

The Bernoulli and continuity equations are the mathematical relations most often used for incompressible fluids such as water. For network analysis, a series of these equations must be derived and then solved through techniques such as the Newton-Raphson, Linear theory and Hardy-Cross methods (Walski, 1983:59). These models require tremendous amounts of data - pipe diameters, lengths, roughness coefficients, head loss coefficients, and so on. For their intended purposes, these models do an excellent job (Davis, 1979:237). Kentucky Pipes, Water Distribution System Analysis and Optimization (WADISO) are just a couple of the many programs available.

Suppose however, that a macro analysis of supply vs. demand is desired. Is there a procedure developed that

takes into account the variance associated with demand and yet does not require the extensive hardware information of typical simulation program?

General simulation languages offer a means of comparing the supply and demand of almost any time dependent process. They are most often used in operations research or Industrial Engineering for service manufacturing functions.

The two capabilities which appear to make them ideal for solving utility problems are continuous segments to solve differential equations and randomized simulation. The following two languages were evaluated by the researcher for use in this problem.

Simple 1. Simple_1 is an interactive simulation language that operates on IBM and compatible microcomputers. The Simple_1 programs are written in Pascal and support a number of features that make it an attractive tool for simulation.

The program works in a modeling environment that coordinates on-line tutorials and a full screen editor connected to the compiler and run-time system.

> Errors detected by the compiler or run time
> system initiate a call to the editor to isolate
> the error and speed up the edit-compare-debug
> model development cycle. (Simple_1, 1989:5)

The primary impetus of using a simulation language of this type is the powerful statistics collection capabilities

on elements of user defined arrays. Statistical clearing

functions can be initiated any time as well. Compiled

models may be stored on disks and later run as application

programs using the "Runsim" utility. Thus, the model itself

can be run on almost any IBM compatible microcomputer

without virtue of the main programs. Simple_1 also has a

built-in graphics and animation package that allows the

operator to view the simulation in action (Simple_1,

1989:5).

A continuous simulation feature is also included to

define variables using first order differential equations.

The continuous segment is done using a Runge-Kutta Fourth

Order Fixed Step procedure with the step size assignable by

the modeler. The combining of the discrete and continuous

sections into one file represents a programming advantage as

well. Several convenient syntax features have been

integrated as well. Variable names can be used instead of

preset variables and names can be up to twenty characters in

length (Simple_1, 1989:5).

SLAM - Simulation Language for Alternative Modeling.

SLAM II is an advanced FORTRAN based language capable of

supporting both discrete and continuous model developments.

SLAM II can be run on both microcomputers and mainframe

workstations. SLAM II has existed for several years (since

1986) and is widely accepted by a great number of
institutions (SLAM, 1989:5).

Current versions of SLAM are available with material
handling packages (MH extension) and graphics capabilities
(TESS) to facilitate user capabilities. Advanced versions
of SLAM have increased user-friendliness through menu-driven
screens and automated programming functions. In addition,
the developers of SLAM have increased the statistical powers
of SLAM with a probability distribution package called AID.
The number of probability distributions supported by SLAM is
superior to that of Simple_1 (SLAM, 1989:5).

III. Methodology

Overview

The following section contains the information and
process for solving the research objectives stated in
Chapter 1. Data collection techniques and specific methods
employed in answering the research questions are also
discussed.

Analytic - Methodology for Objective One

The purposes behind Objective one were simply to 1)
understand the system and its components, 2) obtain the
necessary information on it and 3) make rough determinations
as to where the problems lie from established analytic
procedures. Interviews with the superintendents, design
engineers and technicians familiar with the system were used
primarily to gain understanding and a "feel" for how the
system works. The historical data and documents provided
the quantitative information needed to accurately portray
the system. Face-to-face interviews and actual system data
are primary sources and represent the most precise
information available (Emory, 1985:133). There should be
sufficient data, such as dates, well flowrates, storage
levels and operating schedules to provide background and
allow for solution of standard as well as stochastic
techniques. Specifically, the future demands on the system

will be estimated from historical demands and a cursory review of proposed construction projects. Water supply sources will be reviewed as to their current outputs and future potential. Storage requirements will be analyzed with military and civilian storage requirements. The understanding of water systems in general will be undertaken primarily through a review of the literature and consultation with experts in the field.

Simulation Modeling - Methodology for Objective Two

Problem Formulation. The modeling of water distribution systems should be adaptable to a high level computer simulation language. The wells and contract supplies provide a continuous flow of water. The storage tanks are analogous to inventory queues as in a typical discrete event simulation. The variable demand of the users can be thought of as the activity.

Parameters of interest are the daily maximum, average, and minimum storage levels in the tanks and the time to reach steady state from a storage level of zero. If there is no water in the storage tanks and the supply flowrate is less than the demand flowrate, then there either will be insufficient pressure or an actual lack of water to the system. The differential equation that represents the change in storage is given by:

$$\frac{\delta Q}{\delta t} = \text{Rate in} - \text{Rate out} \qquad (1)$$

in terms of the Nellis system

$$\frac{\delta Q}{\delta t} = (\text{Base Wells} + \text{CRC}) - \text{Base Demand} \qquad (2)$$

integrating, this becomes

$$Q = Q_o + t \quad \{(\text{Base Wells} + \text{CRC}) - \text{Base Demand}\} \qquad (3)$$

where,

    Q = tank storage at a particular instant (gals)
    Q_o = the previous tank storage level (gals)
    Base Wells = the supply flowrate of the Nellis wells
               (gpm)
    CRC = the Colorado River Commission supply flowrate
       (gpm)
    Base Demand = the instantaneous water used by the base
               (gpm)
    t = the time interval (minutes)

Input Data Analysis. The two supply sources, base

wells and the CRC supply, were initially assumed to be

constants affected only by a mechanical on/off mode

dependent upon storage levels. The base wells flow is

mechanically pumped and constant flow is reasonable. Actual

base data was available to estimate these flows.

Data from the Colorado River Commission showed the CRC

flow fluctuated throughout the day. It was later determined

that the CRC flow is gravity fed and dependent on the

current demand, the storage levels and the system hardware.

In order to predict the CRC flow a regression equation was

developed based on the demand and total base storage. The regression equation:

$$y = .0156*\text{Hourly Demand} - .003544*\text{Current Storage} + 219.2$$

The regression had an overall fit or F value of 76.74 with a corresponding p-value of zero. Along with the overall validation of the simulation model, this appears to be a valid approach for approximating the CRC flow.

For simulations involving future growth, the CRC flow was estimated as an average value because the system conditions are not known and a regression line cannot be derived.

The base demand is a probability distribution that varies over time. That is, the demand varies over a daily cycle (Figure 3). A demand curve was created based on historical data and computed as a percentage of the daily demand. A particular probability distribution was established for the daily demand. The probability was hypothesized to be normally distributed.

In order to check and see if the real world data agree with the assumed theoretical form, a goodness-of-fit test was applied (Kleijnen, 1974:66). The Kolmogorov-Smirov (KS) test was used because the sample size was relatively small (less than 100). Using the AID computer statistical program, the hypothesized distribution was accepted (see Appendix C). Probability distributions of the two hour

demand periods also appeared to be normally distributed based on histograms and Rankit plot graphs.

In order to obtain the most accurate reproduction, the actual historical data was used to validate the model, and once validated the theoretical distributions were used (Kleijnen, 1974:68).

Transient Phase. After the probability distribution was completed, these subsystems need to be incorporated into the overall model. This model will be manipulated over time and consequently the starting conditions must be specified.

In order that the model mimic the day-to-day operation of the real system, steady-state must exist before the experimental conditions can be applied. This is because a water system is a continuous activity; it is not like a shot or military mission which has a start-up from ground zero every day.

> The most common method of determining the truncation point is to examine a plot of the response from a pilot simulation run. The truncation point is selected as the time at which the response "appears" to have reached steady state. (SLAM, 1986:43)

Further guidance also suggests throwing away a little extra beyond the apparent point of steady state (Litko). For each of the experimental designs attempted, a series of five pilot runs were accomplished. An appropriate moving average was calculated and the results graphed to visually estimate a conservative steady state point.

Daily Demand

Thousand Gallons

Time of Day

—＊— Mean Demand　—十— Upper 96%　·＊· Lower 96%
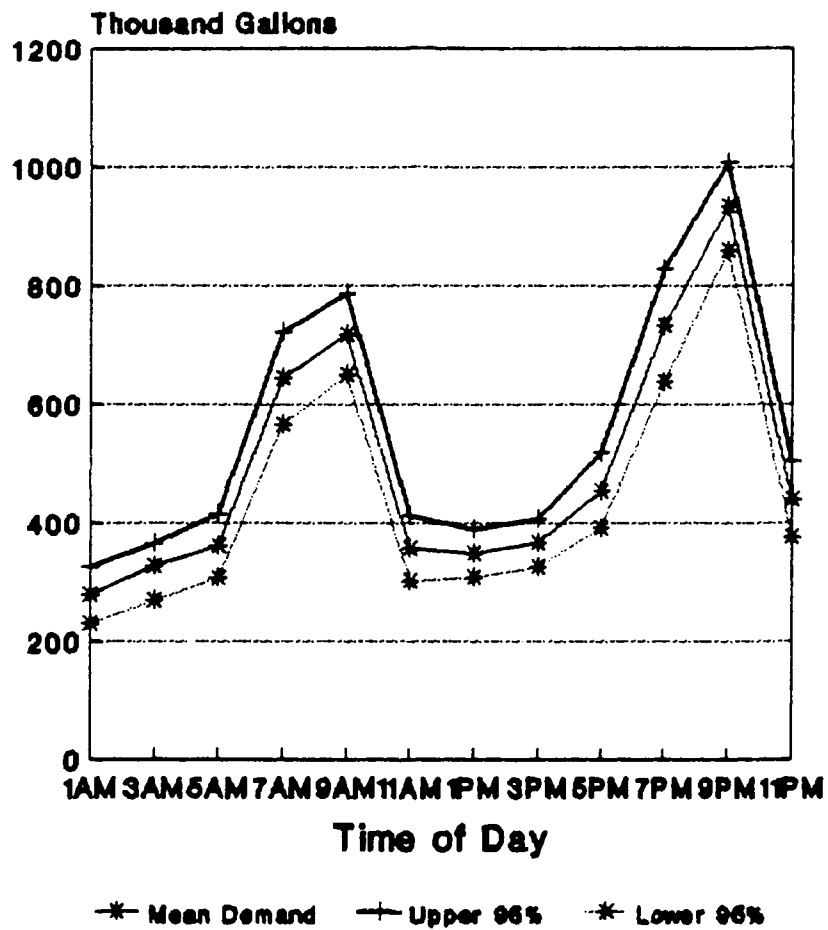
Figure 3. Daily Demand Pattern

43

Correlation and Length of Run. To achieve a
satisfactory number of independent, random samples,
observations were taken within and across replications.
Correlation resulting from both the initial start-up
conditions and the transients after each experimental
observation must be passed before an experiment can begin.
To achieve this, each run was divided using the subinterval
technique to reduce correlation. In order to assume each
subinterval was independent the total base storage variable
was reset to idle and the transient disregarded or it was
reset to its average validation value.

A specified statistical accuracy must also be achieved
in order to give the results credibility. Confidence
intervals were calculated using the statistical formula
based on the familiar "t" statistic:

$$t = \frac{y - \mu_0}{s/\sqrt{n}} \qquad df = n - 1 \qquad (4)$$

Converting this to a confidence interval:

$$\bar{y} - \sqrt{\frac{var(\bar{y})}{N}} \cdot t_{N-1}(\alpha/2) \leq \mu \leq \bar{y} + \sqrt{\frac{var(\bar{y})}{N}} \cdot t_{N-1}(\alpha/2) \qquad (5)$$

from

$$\bar{y} = 1/N \cdot \sum_{n=1}^{N} \bar{y}_i \qquad \text{and} \qquad var(\bar{y}) = 1/(N-1) \cdot \sum_{n=1}^{N} (\bar{y} - \bar{y})^{**2} \qquad (6)$$

where y' represents an individual sample. By using a sample size greater than 30 and application of the Central Limit Theorem, a normal distribution can be assumed. To confirm this both the histogram and Rankits Plot was observed from each run as in run three (Figure 4). From the initial point estimate, the correct number of runs was calculated using:

$$\frac{\triangle_1}{\triangle_2} = \frac{(M*N)_2 **1/2}{(M*N)_1 **1/2} \qquad (7)$$

M - number of replications
N - length of replications
$\triangle$ - variance of output
1 - initial run
2 - next run

and the estimate will then be within the confidence level, α.

Verification. After a model is constructed, checks must be made to ascertain whether the intended actions are taking place when the model is run. During the development phase, print statements were inserted into the program at appropriate points and actual data values were saved to a file. From this file manual calculations were done to ensure the program was acting as expected. Basically, the base demands were subtracted from the total supplies coming in added to what was previously in total storage. The time of day was also checked to make sure that it correlated as well. The Runge-Kutta integration procedure caused some

45

problem because values were not exact; however this was

circumvented by using "difference" equations since the basic

relationships were linear. Once completed, values

calculated correctly.

Validation. After completing the model it must be

validated to ensure that it is reasonably accurate for its

intended purpose (Sargent, 1988:33). In this case, three

methods proposed by Sargent were chosen to evaluate and

compare validity:

> Event Validity: The "events' of occurrences of
> the simulation model are compared to those of the
> real system to determine if they are the same. An
> example of events are deaths in a given fire
> department simulation.
>
> Extreme-Condition Tests: The model structure and
> output should be plausible for any extreme and
> unlikely combination of factors in the system,
> e.g. if in-process inventories are zero,
> production output should be zero. Also, the model
> should bound and restrict the behavior outside of
> normal operating ranges.
>
> Historical Data Validation: If historical data
> exist (or if data is collected on a system for
> building or testing the model), part of the data
> is used to build the model and the remaining data
> is used to determine (test) if the model behaves
> as the system does. (Sargent, 1988:34)

The Event and Extreme-Condition tests were performed by

dramatically varying the inputs - well supply, CRC supply

and the base demand - and seeing its effect on the total

base storage. For example, if the supply flowrate is

dramatically increased while the demand is decreased the

HISTOGRAM OF TBSMIN

LOW   HIGH   (X 10^3)
       N

LOW	N	HIGH	
-0.4		0.1	
	4		
0.1		0.6	
	10		
0.6		1.1	
	32		
1.1		1.6	
	29		
1.6		2.1	
	22		
2.1		2.6	
	9		
2.6		3.1	
	3		

CASES INCLUDED 109   MISSING CASES 0

RANKITS VS TBSMIN

RANKITS

APPROX. WILK-SHAPIRO 0.9886   109 CASES
PLOTTED
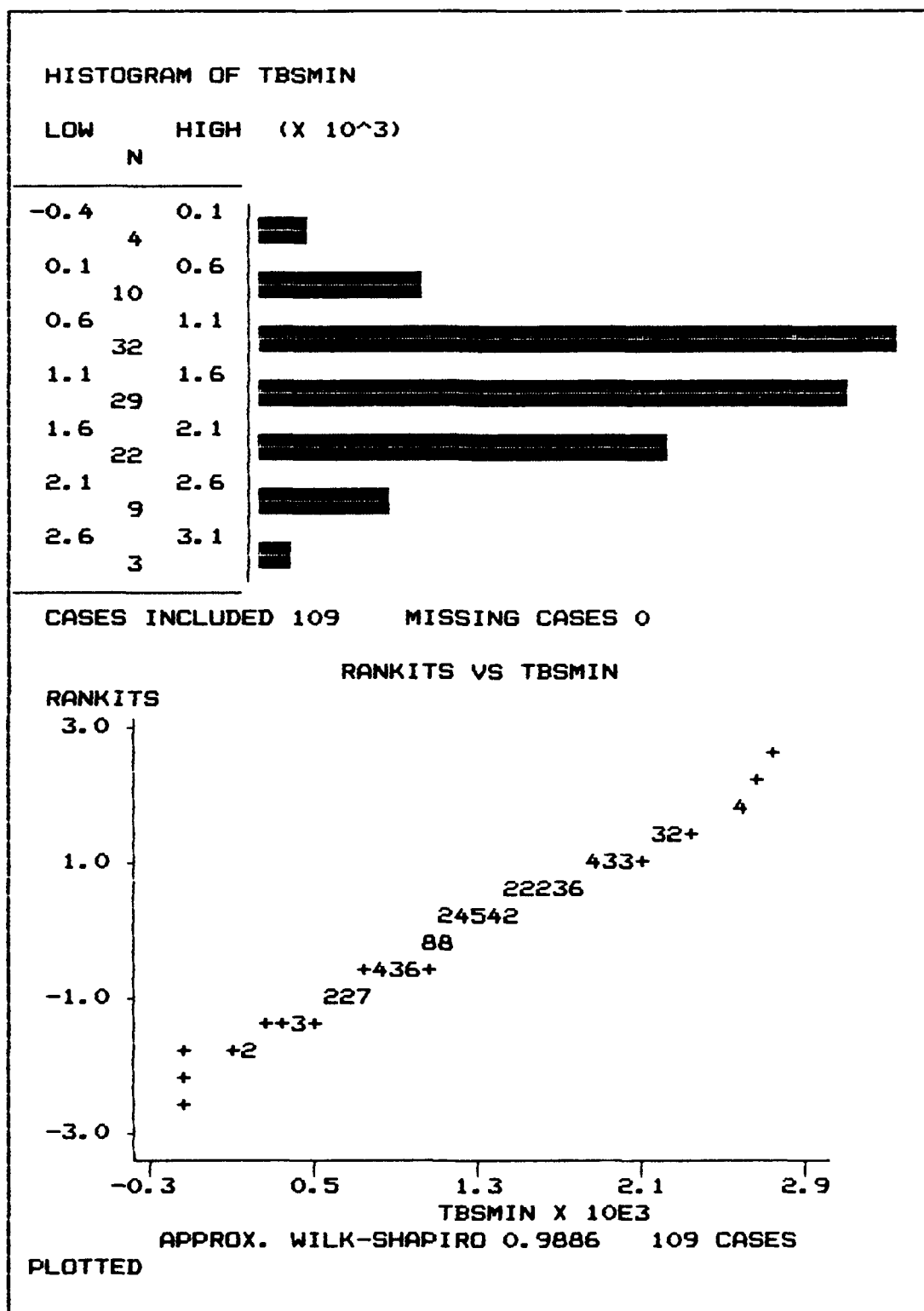
Figure 4.   Histogram and Rankit Plots for Run 3

47

tanks stayed full as expected. Also, if the demand pattern is shifted the tank levels shift as well. More will be discussed and calculated on validation in chapter four.

Experimental Design

The parameters, variables, and relationships that differentiate one "setup" or test situation from another are called factors. They can be either quantitative or qualitative. Quantitative factors may have many levels such as the specific value of a probability distribution. Qualitative factors can be considered at only a few levels and tend to focus on making a decision, say perhaps like a policy decision (Kleijnen, 1974:76). The factors that will be considered are the base fire loads, the future growth loads and the supply operating schedules. The first two are quantitative factors and the third is a qualitative factor.

The first set of simulations was to measure several factors under current conditions (see Table III). Steady-state simulations were used to measure the system under various conditions such as increased well outputs and well scheduling. A terminating simulation was used to test various fire demand loads on the system. Air Force manuals give standard water requirement figures based on the size of the largest building on base, but several other cases were considered.

Table III. Current Conditions Simulations

Simulation Runs Under Current Conditions
(No increased demand and current storage available)

Run No.	CRC Flowrate	Wells Flowrate/ Breakperiod	Fire Demand
1	Current	Current/8 hrs	-
2	Current	1985 flowrates/ Current	-
3	Current	Current/ 0	2500 gpm @ 1800
4	Current	Current/0	4000 gpm @ 1800

The second set of simulations were to test the base storage at a future date with an increased demand (see Table IV). Originally, a three factorial design with two levels was to be accomplished. The three factors to be varied were: total storage available, the CRC flowrate and scheduling of the wells. The two levels would be the highest and lowest possible expected values for each factor. Eventually however, several other cases were run because of values obtained from conventional storage analysis.

The future growth of the water demand is a steady-state increase that can also be approached in two ways. Either individual projects can be incrementally added or the existing total demand increased by a percentage of say one or two percent for example. The difficulty in dealing with

individual additions is that not only must the increase in
water be calculated but its demand curve must be generated
as well. Otherwise, it must be assumed that it follows the
overall demand of the rest of the base. Future water
requirement simulations were made with the following
assumptions: increased demand of 30%, 12 hour curtailment by
the CRC, and a 16 hour well schedule.

Table IV. Future Runs Simulations

Simulation Runs Under Future Conditions

Run No.	CRC Flowrate	Wells Replenishment	Storage Available
6	10 cfs	8 hours	8 mg
7	10 cfs	24 hours	8 mg
8	16 cfs	8 hours	8 mg
9	16 cfs	24 hours	8 mg
10	10 cfs	8 hours	12 mg
11	10 cfs	24 hours	12 mg
12	16 cfs	8 hours	12 mg
13	16 cfs	24 hours	12 mg
14	23 cfs	24 hours	12 mg
15	16 cfs	8 hours	10 mg

IV. Analysis of Results

Overview

Up to this point, the research has involved formulating a problem, conducting a review of relevant literature, building a model and developing an experimental design to answer the research questions. This chapter will analyze and interpret the results of conventional procedures and the model output data. First, historical data will be used to compare the supplies and storage versus the demand. Secondly, a look at the Simple_1 output will help to determine the transient phases and validate the model. Finally, runs testing various parameters will be presented and analyzed.

Demand

The water problem at Nellis is both a function of demand as well as supply. Annual consumption, peak day and peak hydraulic flows are interrelated, however these flows are projected separately for each instance. The following figures portray these demands for their respective time units. Figures 5 and 6 show the actual annual consumption versus available supplies of water. The available supplies of water are based on 24 hour operation of the wells and the contract amount of 6 cfs from the Colorado River Commission.

51

1987 Supply Vs Consumption
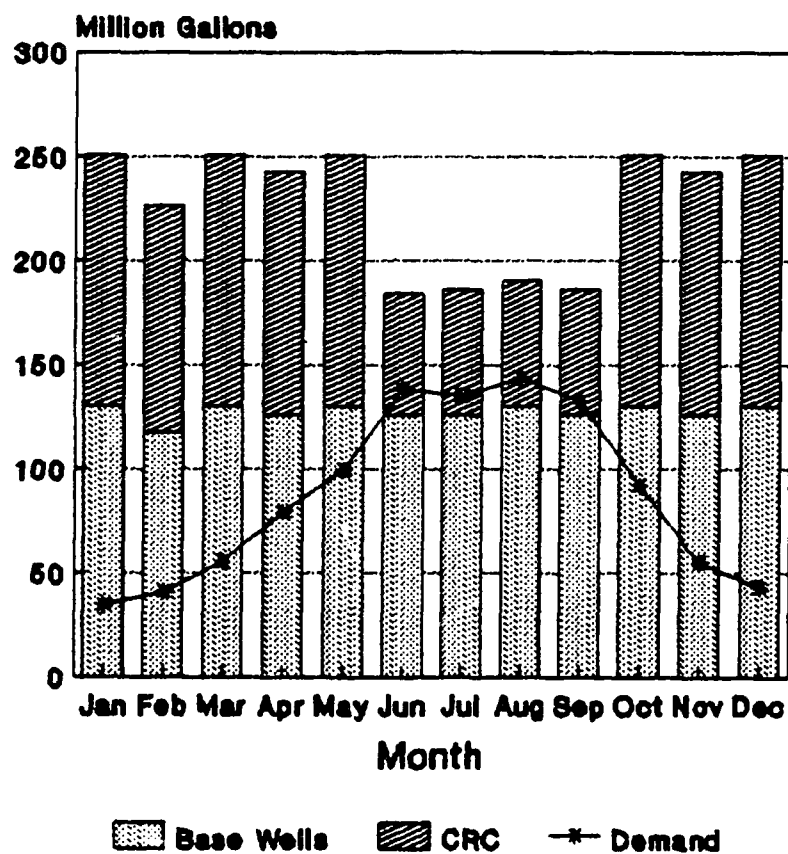
Figure 5. 1987 Annual Demand and Supply

52

1988 Supply Vs Consumption
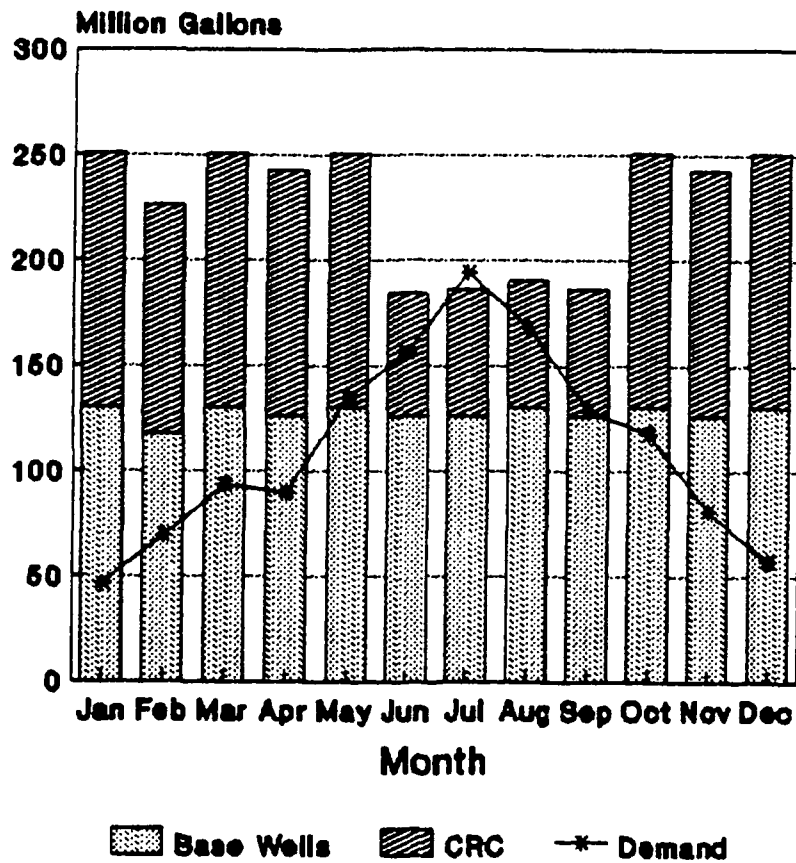
Figure 6. 1988 Annual Demand and Supply

53

Because of low winter usage, Nellis uses an annual amount of water considerably less than that available.

The flows available in the summer, however, drop dramatically because of the 12 hour curtailment. The demands are very close to supplies and Figure 6 of 1988 points out that the demand during June required a flow greater than 6 cfs from the Colorado River Commission. Figure 7 shows the daily demand and supplies. Again, the reduced flows during curtailment are drastic. The area between the demand curve and the supplies available must be accounted for in storage as well as increased flowrate during non-curtailment periods.

The historical demand pattern (Figure 8) from 1980 to 1988 shows significant fluctuation but with an upward trend. According to staff personnel most of the fluctuation can be ascribed to: weather conditions, different water conservation policies and special projects and exercises. A new park and two new baseball fields constructed in 1987 appear to have caused the sharp increase for 1988. The straight percentage increase from 1980 to 1988 is approximately 36%. With new projects planned such as a new 9 hole golf course, a new football field and a par course this percent increase should continue by at least as much (Keller, 1989). For purposes of analysis, a growth of 3 percent per year will be used for the next ten years or 30 percent.
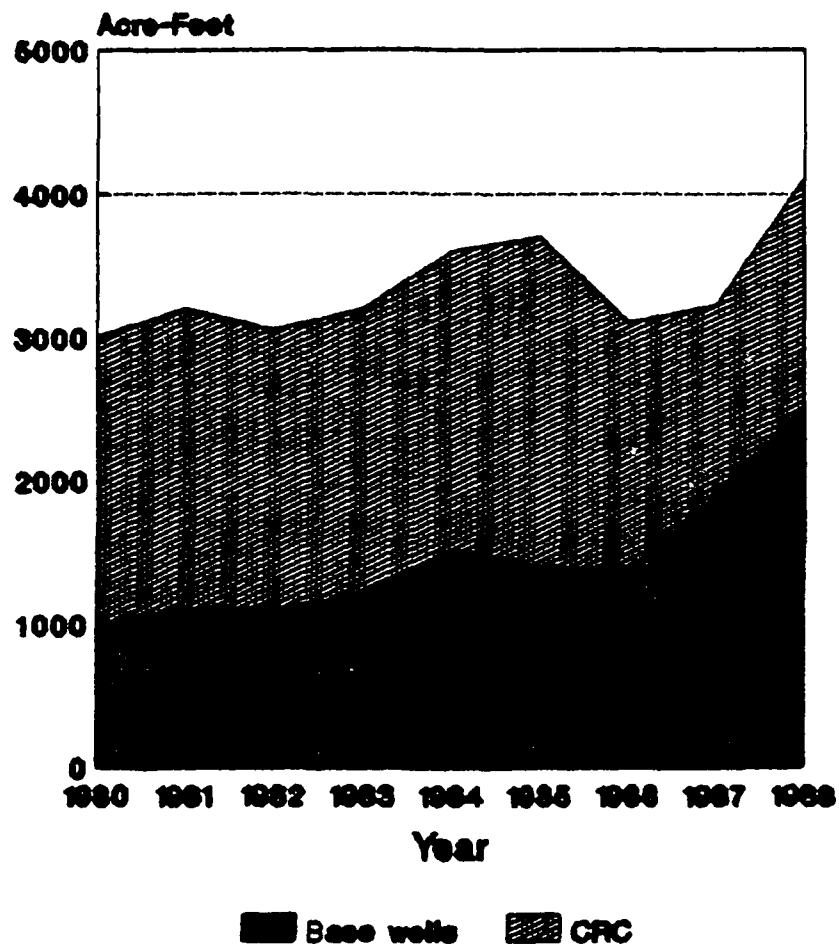
Figure 7.   Total Annual Consumptions

Average Daily Demand
June 89

Thousand Gallons

Time of Day

Base Wells   CRC   ──*── Demand
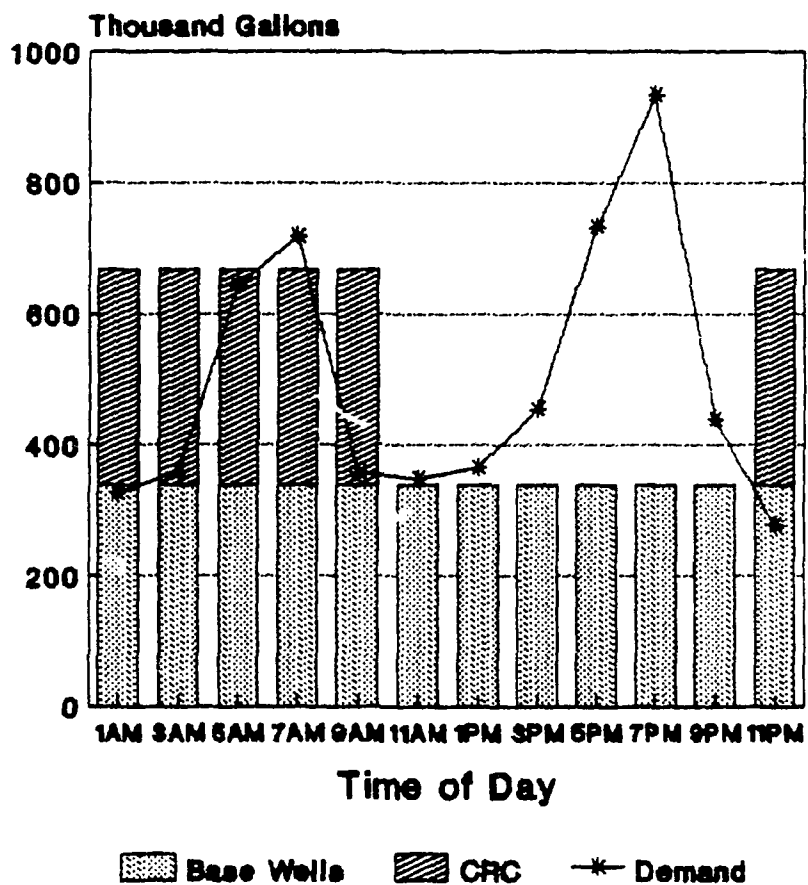
Figure 8.   Daily Demand Pattern for June 1989

One other item of interest is the distribution of the
water usage, Figure 9. Approximately 50 percent of the
demand goes to the housing area. The point is that a large
percentage of the load goes for basic domestic purposes.
Even a short duration outage would be unacceptable. A large
percentage of the water also goes toward the golf course.
In an emergency or extended outage, the golf course could be
shut off without catastrophic results. Correspondingly, a
newly planned nine hole golf course should use a substantial
amount of water as well.

Wells

Table V shows the current well output rates. The
engineering analysis by URS in 1986 gave the following data
(Table VI) on the then current well outputs and possible
well outputs with the upgrading of the desert well
transmission line.

As can be seen, the rates have dropped substantially in
the past several years. While the increased demands are
obviously contributing to the Nellis water problem, the
decreased output of the wells is just as substantial.
According to Gene Clock of the Nevada Water Resources
Department, a large problem within the Las Vegas valley is
the depletion of the underground aquifer (Clock:1989). If
this is in fact the case then Nellis can expect even more

57

Distribution By Area
1988 & 1989

Wherry Housing
22%

Golf Course
21%

Area III
4%

Area II
6%

Manch Housing
23%

Main Base
24%
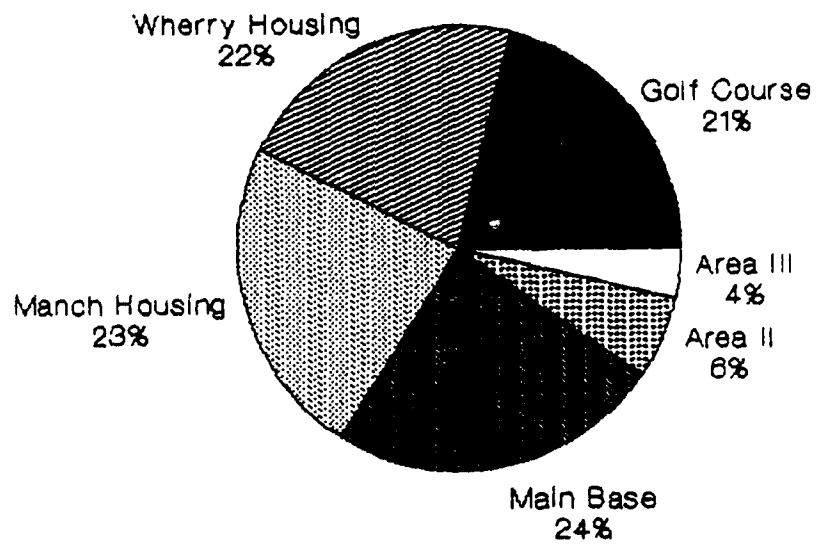
Figure 9. Breakdown of Distribution by Area

58

Table V. Current Well Flowrates, June 1989

| | JUNE 1989 | |
Well No.	GPM	KGALS/HR
Desert Wells		
1	118	7.1
2	260	15.6
4	230	13.8
8	198	11.9
Base Wells		
6	278	16.7
7	298	17.9
11	252	15.1
12	345	20.7
13	350	21
14	202	12.1
Area II wells		
2	–	–
3	–	–
4	–	–
5	83	5
Total	2752	165.2

Table VI. Historical Flow Rates, 1985

	Flow Rate (in gpm)	Daily (in mg)	Annual (in af)
Well Production	3610	3.47	3881
Well Production with upgrade to desert transmission line	4250	4.2	4720

decreased production from its wells. In addition, the local community, North Las Vegas, has experienced land subsidence and attributed some of this to "mining" of the aquifer. Subsidence is defined as sections of real estate actually starting to sink and cause damage to facilities. This could become a political problem if the subsidence becomes directly attributable to the Nellis wells. Mr Robert Rodowick, current water shop superintendent, has recently taken samples of the water depth in the well casings of the various wells.

Surprisingly, the levels are equal or higher than they have ever been. This indicates sufficient water but that some type of restriction exists such as clogged perforations in the well casing.

Well production is a function of three things: groundwater supplies, pump capacity and well water rights. The current well water rights are shown in Table VII.

There is a large discrepancy between the actual flows from the wells and the base water rights. Well No. 10 is no longer in operation. Should Nellis elect to operate its wells for the long term future, an effort should be made to rectify this with the Nevada Water Resources. In accordance with Nevada water rights, these well permits are non-revokable and Nellis can continue to extract water regardless of decreasing supplies.

Table VII.   Well Permits

Permit No.	Well No.	cfs	gpm	annual af/yr
13764	1	.46	206	333
13765	2	.6	269	434
13766	3	.46	206	153.2
13767	4	.5	224	362
13769	6	.55	247	184.2
13770	7	.55	247	0 *
16936	10	.44	198	318.5
17522	8	.6	269	434.4
18722	8	.76	341	418.2
Total		4.92	2207	2637.5

* annual consumption included with well 6

The typical annual operating schedule for the wells is to shutdown the wells in winter and rely on the Colorado River Commission. In summer the wells provide the majority of the water supply (see Figure 10). Mr. Rodowick has also stated that because of the low storage levels, the wells are operating 24 hours a day, almost seven days a week and have been since the beginning of summer.

Contract Water Supplies

The current temporary agreement with the CRC allows Nellis to take up to 10 cfs or 4 cfs greater than the current contract amount of 6. The mean flow for the typical month of June 1989, however was 163.6 kgal/hr or 6.1 cfs. Yet the average storage quantities during the day never

Figure 10. Operation of Wells vs CRC

approached the maximum possible storage of 5 mg (see Figure 11). Optimally, the system should receive the maximum amount of water until the tanks are filled. The reason appears to be because of hydraulics. The water level in Tank 563, the main base tank, is monitored by the CRC to control the CRC flowrate. A sophisticated computer program of the Southern Nevada Water System (SNWS) called the Supervisory Control program controls the flow and attempts to allocate water among the other users and Nellis (Grasso, 1989). In general, it works by gravity feeding water to Nellis from the CRC tank on Sunrise Mountain depending on the water level in tank 563 and the system demand and the demands of other users. Because of close proximity to the CRC supply and residual system pressure, tank 563 (.5 mg) tends to fill much faster than the 3 mg reservoir (Dorsey, 1989), (Rodowick, 1989).

If Nellis is to appreciably increase its water supply, the Colorado River Commission should be considered initially. The hardware connection is already in place and the cost per gallon should be the lowest since CRC is the primary source for all the water users. In order to do so however, one of the other five users must agree to lose part of its allocation (Edwards, 1989). Recently, a bill went before the county council to re-evaluate the current allocations for conservation reasons, Assembly Bill 487 -

63

Average Daily Storage
June 89

Million Gallons
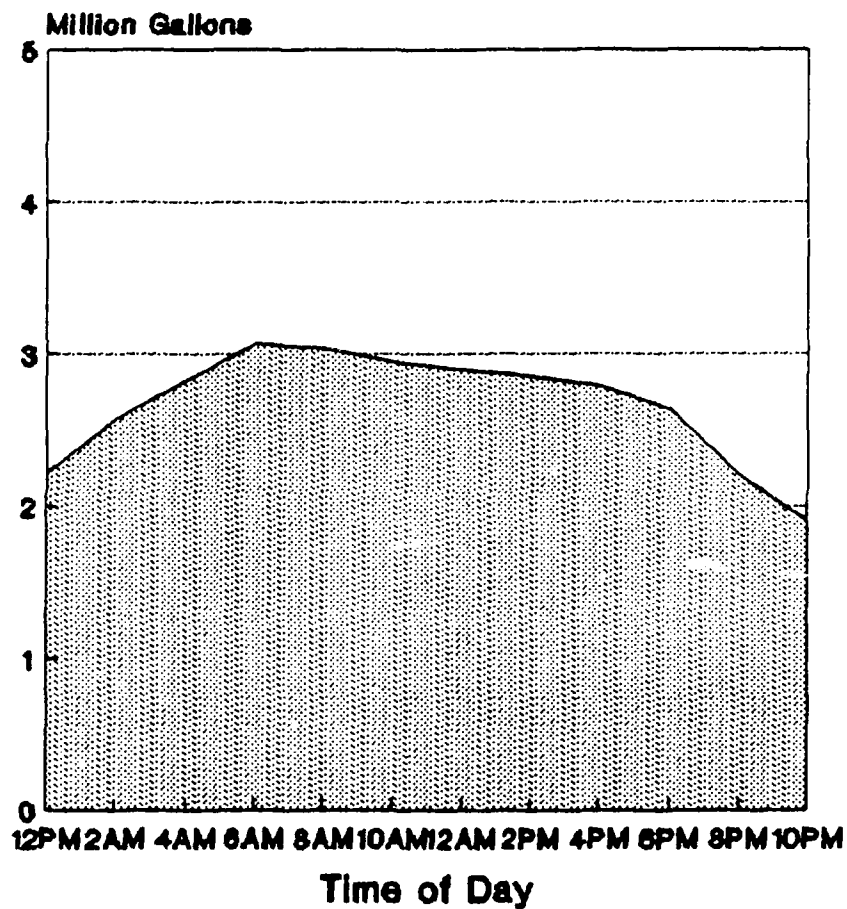
Time of Day

Figure 11.   Storage Levels Vs Time of Day

Water Entitlements - Renegotiation of Water Allocation.
This bill was sent forward but never passed.

Recent discussions with Mr. Bud Dorsey, the current
Nellis utilities engineer, have revealed that negotiations
for CRC allocations with the other users may be next to
impossible. Because of the increasing growth within the Las
Vegas valley there is great reluctance on the part of the
other five water users to relinquish any part of their
allocation. Lack of water will limit development and
estimates have been done showing the entire valley may peak
out Nevada's allocation by 1995 if growth continues (Dorsey,
1989). For Nellis to negotiate a substantial "bargaining
chip" will have to be found.

For the first time in recent history, Nellis was
required to break CRC curtailment in June 1989. The bill
came to a total of $32,000. Once curtailment is broken, the
charge covers the entire rest of the month even if Nellis
should call for water during curtailment again. It should
be observed that while this appears significant, compared to
the monthly summer electric bill ()$1,000,000), it is small.
Therefore, breaking curtailment and taking water could be an
option (Dorsey, 1989). If Nellis did not run its wells
during curtailment period and took CRC water instead, the
monthly electric bill would be significantly reduced.

The next alternative for Nellis will be to contract with one of the five users as a customer. This will be substantially more expensive than CRC water because of the extra "middle man." Pre-arranged contracts to receive water would give assurance to future supplies however.

Because of future demands and possible wellwater supply reductions, the following is an attempt to calculate future requirements. Assuming the wells are still operational and using the following figures:

Table VIII. Future Supplies Assumptions

5.6 mg/day (mean daily demand, summer - 1988 and 1989)
30 percent growth (3 percent per year, 10 years)
16 hour well operation schedule (AFM 88-10)
12 hour curtailment from the Colorado River Commission

Table IX is a compilation of possible combinations of future water supplies. Several of these were tested with the simulation model to monitor steady state storage levels.

Alternative Source Costs

The following cost comparison was performed to give an approximate ranking in terms of cost, Table X. Prices for the Colorado River Commission and the city of North Las

Table IX.   Future Supplies

	Flow Rate (in gpm/cfs)	Daily (in mg)	Annual (in af)
Current Well	2750	2.64	2957
Current CRC	2690/6	1.94	4000
On-Curtailment CRC or another contract source over 24 hour period	3750/8.4 1875/4.2	2.7	1000
Future Well with well and transmission line upgrades	4250	4.1	4592
Current CRC	2690/6	1.94	4000
On-Curtailment CRC or another contract source over 24 hour period	1725/1.92 862/.96	1.24	1000
Current Well	2750	2.64	2957
Increased CRC	6725/15	4.84	4000
Future Well with well and transmission line upgrades	4250	4.1	4592
Increased CRC	4483/10	3.2	4000
Future if Wells are Not Operational	0	0	0
Increased CRC	10,311/23	7.4	6000

Vegas (as an alternative source) were readily available (Dorsey, 1989)

The base wells water costs were calculated using the nominal horsepower for each well pump and current electrical rates for the base during curtailment. From a pure cost perspective, the purchase of water from a source outside of the CRC incurs a substantial increase.

Table X. Cost Comparisons of Suppliers

Source	Cost
CRC	$.20 -$.40/kgal plus $32,000 on curtailment
North Las Vegas	$.70/kgal
Base wells	approximately $.15/kgal

Storage Requirements

The following calculations are both military and civilian storage requirements using data from the summer of 1988 and June 1989. From the storage requirements stated in chapter 2, the Air Force storage calculations are as follows:

Air Force Requirements.

Item 1. 50 percent of the average total daily domestic requirements plus all industrial requirements

5,605,000 Gallons/day - average summer demand, 1988-
    1989
5,605,000 ÷ 2 = 2,802,500 Gallons

       Item 2. Fire demand plus 50% of the average daily
demand reduced by the amount of water available during the
period of the fire

    2,500 gpm - Fire Demand for 4 hours for bldg 20
    2,802,500 gallons - 50% of average daily demand from
       Item 1
    2531 gpm - total well output (fire during curtailment)
       (2500 gpm x 60 min x 4 hours) + (2,802,500 ÷ 24
       hours x 4 hours)
- (2531 gpm x 60 min x 4 hours) = 460,000 gallons

       Item 3. The sum of Items 1 and 2 reduced by the
amount of water available in 24 hours under emergency
conditions

    2,802,500 gallons - Item 1
    460,000 gallons - Item 2
Assuming no supplies
    (2,802,500 + 460,000) - 0 = 3,262,500 gallons
Assuming no Wells
    (2,802,500 + 460,000) - (2531 x 60 x 24) =
    -382,140 gallons
Assuming no Colorado River Commission supply at 6 cfs
    (2,802,500 + 460,000) - (2630 x 60 x 12) =
    1,325,700 gallons

    Note - The Area II wells were not included because they
are pumped directly into the Golf Course ponds.

    The greatest of Items 1, 2 and 3 is well below the

existing total storage of 5 million gallons and there is

still little storage under current conditions. Any less

storage should only exacerbate the problem. Increasing

demands combined with the Colorado River Commission schedule

caused wide fluctuation in storage levels. For this reason,

it is   t that Nellis falls into the exception noted in AFM

88-10. The typical civilian storage quantities will be
calculated as well.

Civilian Storage Requirements.

Standby Storage – supply peak demands for a 24
hour period in the event of a primary source failure.
Normally, the largest source would be chosen to fail in this
case, the CRC. Because of the CRC's reliability as well as
the political and environmental problems with the base
wells, the loss of the base wells appears more imminent.

    6,830,000 gallons – Peak Daily Demand on 29 June 89
    30 percent – Future growth rate
    2531 gpm – current well flowrate excluding Area II
    wells
    16 hour daily operation of base wells from AFM 88-10

    (6,830,000 x 1.3) – (2531 x 60 x 16) = 6,450,000
gallons
    or 8,879,000 gallons if the wells are not utilized

Equalizing Storage – storage required to meet
daily variations in demand. The determination of equalizing
storage is difficult because of the uncertainty in demands
and future flows. The equalizing storage for Nellis is
based on the following assumptions:

    – Daily demand curve based on Figure 3
    – The CRC allocation is increased to 16 cfs
    – The peak day occurs during the curtailment period and
         the CRC water lasts 12 hours
    – 3 percent growth rate for 10 years is anticipated

    3,193,000 gallons – average demand from 10 AM to 10 PM

    1,824,000 gallons – current average output from wells

70

from 10 AM to 10 PM

$$(3,193,000 \times 1.3) - (1,824,000) = 2,326,900 \text{ gallons}$$

or 4,150,900 gallons if wells are not operational

Fire Demand Storage. The maximum fire demand was based on building 20, a building of normal construction with 56,000 square feet. According to EM 1110-345-228, the required fire flow is 2,500 gpm for 4 hours

Operational and Flexibility Storage. The operational storage required for the base wells already exists in wet well facilities 561, 490, 10113 and the golf course ponds. The booster pump stations associated with the tanks are equipped with emergency power and have multiple pumps. The system has proven to be effective and reliable.

Because Nellis does have difficulty utilizing its full allocation from the CRC, a wet well storage tank near the CRC intertie would help maintain the CRC delivery pressure. This operational storage could be used as standby storage as well.

Summary

Two cases were considered for total storage of the Nellis system - one with the wells at their current level of output and one with use of the wells discontinued, Table XI. These two cases were considered because the base wells may be shut down if they are directly attributable to land

71

subsidence. In order to prepare Nellis for the future and increase system reliability, Nellis may want to consider construction of this storage ahead of time.

Table XI. Storage Summaries

	With Wells	Contract Only
Standby	6,450,000	8,979,000
Equalizing	2,236,900	4,150,000
Fire	600,000	600,000
Operational	0	0
Total	9,286,900	13,629,000

Assuming a 95% efficiency, this would mean Nellis should have a total storage of approximately 10 million gallons with the wells still operating. If the wells should be discontinued, 14 million gallons are required.

Model Output Analysis

Transient Estimation. Estimating the transient period for the water system model gives an idea as to how long the system will take to recover from a complete drainage of storage under normal operating conditions. This represents a worst case situation; under emergency conditions some demands could be shut off that would speed up the replenishme , period. For the purposes of simulation, a conservative estimate is preferred. Figure 12 is a graph of the transient period under current conditions.

TRANSIENT RESPONSE

5 runs from starting at zero
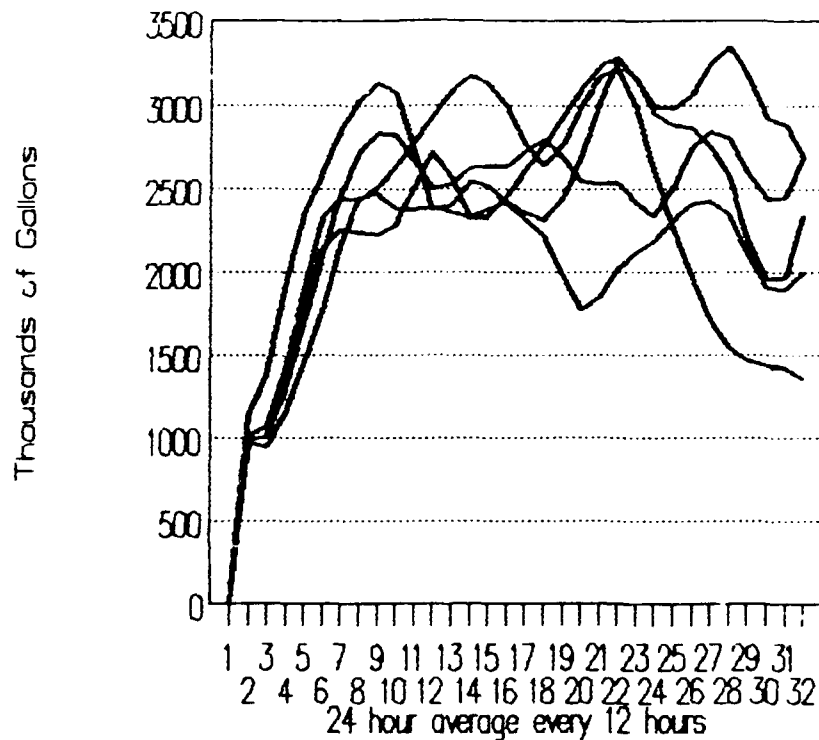
Figure 12. Transient Period Estimation

The graph appears to initially "jump" into steady-state approximately 2-3 days after start-up. It is expected that recovery under normal conditions would take less than a day so that the service area would not be without water. For model purposes, a transient period of 10 days was picked to

ensure no problems with steady-state.

The simulation runs under future conditions required reevaluation of the transient period because of the sensitivity of the proposed systems. The greater total daily supplies were than total daily demand, the faster it reached steady-state. This could be important in that if extra supplies or allocations are not available, then extra storage may need to be built to ensure that supplies do not bottom out.

Validation of Simple 1 Output. Validation is a process of increasing the confidence to an acceptable level so that the inference made from the model is correct for the actual system. A simulation model needs to be validated so it can be used to provide some insight into the behavior of the system. Event, Extreme Condition and Historical Data validation were discussed in Chapter 2. Validity in the context of this chapter deals with testing historical data from the current conditions model and discussion of the input-output transformation.

Using the historical data on total water storage that is collected every two hours, sample means were collected to be used as parameter estimators. From the model output data sample means were also collected for comparison. A "t" test comparison of means was done to see if the model output data was approximately equal to the actual historical data. Four

times were chosen - twelve o'clock (AM and PM) and six o'clock (AM and PM).

Using equivalent means as the null hypothesis and a level of significance, α, equal to .05, the following data was tested using the t statistic (Table XII).

Table XII.   Validation Output

Time	μ	$\bar{x}$	s	n	t
12 PM	2202	2097	507	41	1.3
6 AM	3058	2974	431	41	1.12
12 AM	2880	2943	428	41	.942
6 PM	2621	2772	458	41	2.11

All storage levels pass the .05 significance levels except for 6 PM. The value however is close to passing (t_{crit} = 2.021) and is well within the .02 level of significance. Therefore, the model data will therefore be considered as acceptable.

Interpretation of Runs. A look at the SIMPLE_1 output (text and graphical) reveals significant information about the behavior of the system. Table XIII is a listing of the mean daily minimums and their 95% confidence limits under current conditions.

Table XIII. Current Conditions Simulations

Current Conditions

Case No.	Mean Minimum Daily Storage (kgals)	Std Dev	95% Upper Conf. Int	95% Lower Conf. Int
1	7.9	179	0	0
2	2737	555	2782	2691
3	1279	642	1398	1157
4	945	613	1048	842
5	1840	650	1979	1751

Case 1. Run One was to test current conditions and see if the base demand could be met with the base wells operating on a 16 hour schedule. Because the CRC supply is curtailed during midday (10 AM - 10 PM), the maximum drop in storage occurs at this time. Therefore, the well replenishment period was set up for nighttime from 12 PM to 8 AM. The daily minimum storage is consistently at zero. Allowing the wells to replenish under the current conditions would allow storage to build to an acceptable level.

Case 2. Run two was to test and see what the minimum storage would be if the well rates were returned to their previous 1985 rates with the eight hour replenishment period and upgrade of the desert well transmission line. An

average minimum storage of 2,700 kgals shows a dramatic increase in water supply with the wells back to their original levels and transmission lines. A quick examination of the daily maximum also shows that it approaches the total available storage.

Case 3. Run three was designed to monitor the effects of a fire at the worst possible time of the day, six PM. The fireflow will therefore be required till just before the CRC curtailment period is over. The minimum storage level reached is an approximate average of 1300 kgals with a standard deviation of 642 kgals. Using the normal distribution, the probability of zero total storage occurs in the 2.4% range of the tail.

This seems relatively small, however the water is located in various tanks and dispersed around the base. Even a low probability of zero total storage is serious because the pressure may be too low or water from outer areas may be too slow in reaching a fire.

Case 4. Run 4 was to test an unlikely but possible worst case scenario. The fire load was raised to 4000 gpm for 4 hours also occurring at 6 PM. As expected, the total base storage dropped even further down to 945 kgals. The probability of zero total storage increases to about 6.3%. Again, the same logic applies concerning decreased pressure and dispersion of water.

Case 5. Run 5 was to test the response to a fire at any time during the day. The total minimum storage rises to an average of 1840 kgals at a standard deviation of 650. Occurrences during non-curtailment periods appear to be handled by the CRC flow since it is dependent upon demand and storage levels.

Table XIV is a listing of the mean daily maximum, average and minimum storage levels for future conditions. These values will be used to calculate confidence intervals and compare them with the civilian storage requirements.

Cases 6 and 10. At 10 cfs and no well support, the total water storage cannot accumulate enough to average even a half million gallons a day.

Cases 7 and 11. At 10 cfs and well support under current flowrates, the water again does not accumulate enough to support the base although it is significantly higher than without the wells.

Cases 9 and 13. At 15 cfs and no well support, the result is again the same - the water does not accumulate enough to support the base.

Case 9. Run 9 was to test 15 cfs with well support at current flowrate for 16 hours with 9 mg worth of storage available. The supplies are able to support the base demand; however, the average daily storage does not increase beyond the 95% confidence intervals of 6143 and 5012 kgals.

Table XIV. Future Runs Output

Future Conditions

Case No	Daily Max	Std Dev	Daily Ave	Std Dev	Daily Min	Std Dev
6	745	141	343	152	0	—
7	444	130	105.6	47	0	—
8	6773	673	6078	736	4595	828
9	1816	237	875	178	0	--
10	745	142	343	152	0	—
11	444	130	106	47	0	—
12	10230	351	9529	306	8047	237
13	1816	237	875	178	0	—
14	10780	312	9835	413	6778	533
15	8685	542	7395	603	5518	700
16	11860	1052	10850	1093	7397	1151

If the average standby storage is approximately 8800 kgals,
then sufficient average storage has not been reached.

Case 12. Run 12 tests the same conditions as Run 8
except the available storage increases to 12 mg. The
average available storage has 95% confidence intervals of
9610 and 9447 mg. This is well above the average 8800
kgals required for standby.

Case 14. Run 14 was to test using the CRC flow only at
a flowrate of 23 cfs. It is quickly noticeable that there

is a large variation in the total storage throughout the day. The average daily level has 95% confidence intervals of approximately 9290 and 9176. These too are well above the 8800 kgals required for standby storage.

Cases 15. Run 15 was to check the minimum storage with 16 cfs and 16 hours well production at current rates and 10 mg of storage available. The 95% confidence intervals for average daily storage are 8069 and 7920 gallons. This is somewhat surprising since 10 mg was the calculated future storage. Evidently, the upper level storage limit tended to push the average down. However, 8000 kgals is relatively close to 8800 and a management decision could be made to accept this deficiency.

Cases 16. Run 16 used only a large CRC flow as in run 14 however with increased total storage of 14 mg. The result is increased total storage with intervals of 10,400 and 10,090 gallons.

There were many other cases that could have tested with future conditions. And as more information was gathered even more possibilities were generated. For example, only the base wells and CRC were considered here. In fact, during the latter stages of research it has become obvious that another source may need to be found and incorporated into the model.

V. Conclusions and Recommendations

Conclusions of Objective One.

Research question one was to analyze the Nellis water system using basic deterministic techniques, personal interviews and personal observations.

The Nellis Water System. The Nellis water system has reached a critical point in its capacity in terms of meeting its current and future demands. The current system is composed of 5 million gallons storage and two sources of limited growth potential: base wells and the Colorado River Commission. As listed and shown in chapters 2 and 4, the system has many specific components and interconnections.

Annual demand versus supply figures show that the supply problems peak during the summer months because of electric company curtailments. Increasing demands over the past several years have dropped storage levels within the tanks to the point that during peak consumption/low supply periods the possibility of a catastrophe is very real. This is particularly critical in the late afternoon before 10 PM.

Looking at proposed growth plans and historical data, a conservative growth rate estimate of 30 percent was determined. Comparing demand projections based this growthrate to current water supplies shows a significant shortage. To make matters worse, the availability of

alternative supplies appears bleak as well. New groundwater supplies are not likely to be obtained because of restrictions in obtaining well permits from the state engineer. Contract water sources are currently a possibility although they may be at a premium price and their availability over the long haul is suspect.

Base Supplies. The reduced output of the base wells plays a large part in Nellis' current predicament. According to recent historical documents and interviews, the well flowrates can be increased by vigorous maintenance projects to clean up and/or rebore the existing wells. A policy of constantly running the wells and constant drawdown has evidently caused the well casing perforations to clog. Once the wells are rehabilitated, an operating schedule with a sufficient amount of replenishment time needs to be instituted. Last but not least, operating wells without proper well permits from the State Engineer's office is a violation of state law. Well permits for operating wells need to be established as soon as possible.

The Nellis Transmission System. Having examined the average storage totals throughout the day and the average CRC flow, it is apparent there exists a hydraulic problem preventing the flow of CRC water to the base. Interviews with various personnel have suggested that residual system pressure allows tank 563, which controls the CRC flow, to

fill too rapidly and thus reduce the flow. A hydraulic

analysis needs to be done in order to determine if booster

pumps or valving or perhaps switching metering to the 3 mg

reservoir might be appropriate.

Base Storage. According to calculations performed, the

Nellis system does not apply very well to Air Force storage

criteria and guidance. By typical civilian design

standards, the base is severely deficient. Nellis should

consider the near term solution of construction of at least

another 5 mg of storage to give them a total of 10 mg.

Because of the potential political problems with the wells

and local storage criteria (3 days), an extra 4 mg should be

considered as well.

Two basic problems appear to exist in calculating water

storage requirements for Air Force bases. First, the

military storage requirements are less reliable than those

of civilian counterparts. Civilian guidelines call for at

least a full days demand and the fire load as standby

storage. Air Force requirements notes that only the fire

requirement must be kept on hand -- the storage should be

sized for only half the average daily demand.

Secondly, the Air Force guidance is significantly more

ambiguous. The phrase, "available under emergency

conditions" does not specify what type of condition or what

is affected. The civilian interpretation however calls for

the loss of primary service or the largest least reliable service.

Contract Sources. Contract sources appear to be the best source for new supplies of water. The current allocation of 4000 af at a rate of 6 cfs with the Colorado River Commission is guaranteed in perpetuity at this time. Increasing this rate to 10 cfs or 16 cfs and 6000 af would be the optimal long term solution based on economics. CRC is the primary supplier of water within the valley and its water is cheapest. Political reality however dictates that the other four users will not be willing to give up their share and possibly diminish their long term growth. Because Nellis does not use anywhere near its total annual allocation, it could also receive water during the curtailment period and not exceed its annual limit. This incurs a substantial demand penalty (approximately $32,000/month) but in relation to other utility bills this is relatively insignificant, i.e., the electric bill. The last alternative is to therefore buy water directly from one of the other users to augment the base wells and the CRC. This is the most expensive alternative but guarantees future supplies, see Alternative Supply Costs in chapter 4.

Conclusions of Objective Two

Objective Two was to use a higher order simulation language to macroanalyze a utility system such as a water network.

In order to use a higher order simulation language, the system was modeled using only the water sources and storage tanks and a composite demand. The intent was to mimic an "inventory" system as in discrete simulations.
The purpose was to devise a relatively quick, simple tool to analyze a utility.

The normal distribution was hypothesized to fit the daily and hourly demand and this proved to be true using Rankit plots and the AID computer program. Using time dependent storage levels in comparison with historical data provided a reasonable means of validation. Both statistical testing and qualitative observation of these parameters were used.

Problems occur however when non-linearities are involved that are a function of the system. Pumped fluid systems work well because their flow is more nearly constant. Gravity fed flows however are based on the non-linear Bernoulli equation. This in turn is a function of the many lines and nodes of the system which were not intended to be modeled. These non-linear equations could be

modeled; however, the time and difficulty are prohibitive when hydraulic programs are available.

A complicated, in-depth analysis therefore should use a precise, detailed hydraulic simulation program. For a simplified overview the generic simulation language is acceptable. The great benefit to a hydraulic simulation program is that once the many details are completed, it can be used repeatedly and adjusted to a high accuracy.

The simulation model was used to test several conditions such as fire loading, well scheduling and increased Colorado River Commission flows. The fire loading was done under current conditions and shows the system does not completely drain; however, the low storage levels reached are still of concern. Unless well outputs can be returned to their previous rates, the wells cannot be scheduled for anything approaching an 8 hour replenishment period.

Runs were also done to test the calculated storage levels under future conditions. The average storage levels derived from the simulation also support constructing another 5 million gallons in order to sustain civilian standby storage. Other runs were also done to determine the necessary increased flows for future demands.

```
{This simulation is to model the Nellis Water Distribution
System} DECLARE;
    GLOBALS:
        Well1:
        Well2:
        Well8:
        Well4:
        Well6:
        Well7:
        Well11:
        Well12:
        Well13:
        Well14:
        WellTotal OBSERVE_STATS:
        CRCSup:
        CRCFlow:
        CRCFlowInitial OBSERVE_STATS:
        CRCVlv:
        Curtailment:
        TotalRateIn:
        TotalRateOut:
        TotalBaseStorage TIME_STATS:
        TotalStorage:
        TBS OBSERVE_STATS:
        TBS24:
        TBS2:
        TBS4:
        TBS6:
        TBS8:
        TBS10:
        TBS12:
        TBS14:
        TBS16:
        TBS18:
        TBS20:
        TBS22:
        TBSLowest:
        TBSAv:
        TBSMax:
        TBSStd:
        TBSPlot:
        ON:
        OFF:
        BaseDemand:
        FutureDemand:
        FuturePercent:
```

```
        FireDemand:
        TimeBetween:
        FireStart:
        FireFlow:
        Duration:
        RunNo:
        NumRuns:
        RunLength:
        Day:
        TimeOfDay:
        Index:
        Restart1:
        Restart2:
        InitialNoWaterTime:
        NoWater:
        DailyDemand:
        RestPeriod;


   ENTITIES:
        Control(1);


DEF_SCREEN: Menu,1,1,80,25,YES;
+
```

```
        ┌────────────────────────────────────────────────┐
        │  Nellis AFB Water Supply System Analysis       │
        └────────────────────────────────────────────────┘
```

    This simulation to determine the adequacy of the water
supply system   at Nellis in the event of fire and possible
future growth.   Capt Stephen D.
Grumbach, 1989

    Please set the model's parameter values:

      Colorado River Commission   Base Wells
           Flowrate: Replenishment period:
           Curtailment time:

      Is there a fire?
           Time it occurs: Duration:
           Flowrate required: Time Between fires:

      Future growth   Total Storage
           Percent (%) expected: Available:

      Simulation data
           Length of run: Number of runs:
           Enter a 1 to start or a 0 to re-enter model
parameters: +
DEF_SCREEN: PICTURE, 1,1,80,14,YES;
+
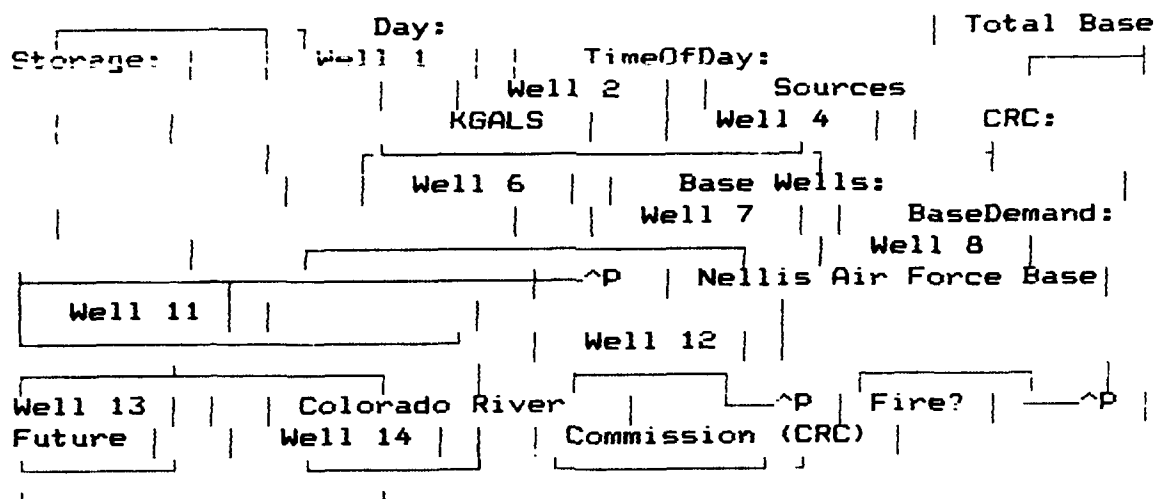
                                88
```

```
     ┌──────┐        Day:           ┌        ┌              │ Total Base
Storage: │    │  │  Well 1  │ │     TimeOfDay:                  ┌────┐
         │    │  │          │ │   Well 2  │ │  Sources      CRC:
    │         │                KGALS  │  │ Well 4 │ │
    │         │        ┌─────────────┐                        │
    │         │        │ Well 6  │ │   Base Wells:
    │         │          │     │ │ Well 7 │ │   BaseDemand:
       │                │   ┌────────┘           Well 8  │
  ┌────────────────────────────────┐──^P  │ Nellis Air Force Base│
  │   Well 11  │ │              │   │
  │            │ └──────────────────┘  │ Well 12 │ │
 ┌─────────────────────────┐     ┌───────────┐         ┌───────────┐
 │ Well 13 │ │  │ Colorado River │ │      ──^P │ Fire? │ ──^P │
 │ Future  │ │  │ Well 14 │ │    │ Commission (CRC) │
 └─────────────────────┘          └───────────┘
 └────────────────────┘
+
DEF_SCREEN: PLOTQ,1,15,80,11,YES;
+                         100

     % of                 80
                              ─
     Total                60
                              ─
     Base                 40
                              ─
     Storage              20
                              ─
+                          0

  FILES:   OUT1,WRITE;
END; {DELCARE SECTION}
PRERUN;
                SET   OFF:=0:     ON:=1:
                      CRCVlv:=1:
TotalBaseStorage:=TotalStorage*0:
Day:=1:          TimeOfDay:=0:
                 Restart1:=OFF:        Restart2:=OFF:
                 STOP_TIME:=STOP_TIME+RunLength:
                 RunNo:=RunNo+1;
                BRANCH RunNo=1, FirstRun:
                            , NextRun;

NextRun         SCREEN,PICTURE,1,1,1,15,0;
                SCREEN,PLOTQ,1,0,1,15,0;
                KILL;
FirstRun        OPEN,OUT1 AS 'run1.DTA';
                SCREEN,Menu,1,1,1;
RunMenu         ACCEPT,20,12,CRCFlowInitial;
                ACCEPT,28,13,Curtailment;
```

89

```
                    ACCEPT,61,12,RestPeriod;
                    ACCEPT,26,16,FireStart,,24;
                    ACCEPT,29,17,FireFlow,0,1500;
                    ACCEPT,48,16,Duration,,24;
                    ACCEPT,59,17,TimeBetween,48;
                    ACCEPT,32,20,FuturePercent,0,50;
                    ACCEPT,50,20,TotalStorage,0;
                    ACCEPT,25,23,RunLength,24;
                    ACCEPT,56,23,NumRuns,1,5;
                    ACCEPT,66,24,Index;
                    BRANCH Index<1,RunMenu:
                                        ,NextScreen;
NextScreen          SCREEN,PICTURE,1,1,1,15,0;
                    SCREEN,PLOTQ,1,0,1,15,0;
                    SET STOP_TIME:=RunLength;
END;


DISCRETE;
{City Supply}
            CREATE,1,Control,24,0;
            SET CRCV1v:=ON;
            ACTIVITY 10;
            SET CRCV1v:=OFF;
            ACTIVITY Curtailment;
            SET CRCV1v:=ON;
            KILL;


  {Well Schedule}
            CREATE,1,Control,24,0;
            SET Well1:=OFF:          Well2:=OFF:
                Well4:=OFF:          Well8:=OFF:
                Well6:=OFF:          Well7:=OFF:
                Well11:=OFF:         Well12:=OFF:
                Well13:=OFF:         Well14:=OFF;
            ACTIVITY RestPeriod;
            SET Well1:=7.1:     Well2:=15.5:
                Well4:=13.8:    Well8:=11.8:
                Well6:=16.6:    Well7:=17.9:
                Well11:=15.1:   Well12:=20.7:
                Well13:=20.9:   Well14:=12.1;
            KILL;


{Base Demand Schedule}
            CREATE,1,Control,24,0;
{12PM}          SET DailyDemand:=NORMAL(5605,581,1);
            SET BaseDemand:=0.0233*DailyDemand;
            ACTIVITY 2;
            SET TBS2:=TotalBaseStorage;
            SET BaseDemand:=0.0274*DailyDemand;
   {2AM}        ACTIVITY 2;
```

```
              SET  TBS4:=TotalBaseStorage;
              SET  BaseDemand:=0.0303*DailyDemand;
{4AM}              ACTIVITY 2;
              SET  TBS6:=TotalBaseStorage;
              SET  BaseDemand:=0.0540*DailyDemand;
{6AM}              ACTIVITY 2;
              SET  TBS8:=TotalBaseStorage;
              SET  BaseDemand:=0.0602*DailyDemand;
{8AM}              ACTIVITY 2;
              SET  TBS10:=TotalBaseStorage;
              SET  BaseDemand:=0.03*DailyDemand;
{10AM}             ACTIVITY 2;
              SET  TBS12:=TotalBaseStorage;
              SET  BaseDemand:=0.0292*DailyDemand;
{12AM}             ACTIVITY 2;
              SET  TBS14:=TotalBaseStorage;
              SET  BaseDemand:=0.0307*DailyDemand;
{2PM}              ACTIVITY 2;
              SET  TBS16:=TotalBaseStorage;
              SET  BaseDemand:=0.0381*DailyDemand;
{4PM}              ACTIVITY 2;
              SET  TBS18:=TotalBaseStorage;
              SET  BaseDemand:=0.0615*DailyDemand;
{6PM}              ACTIVITY 2;
              SET  TBS20:=TotalBaseStorage;
              SET  BaseDemand:=0.0783*DailyDemand;
{8PM}              ACTIVITY 2;
              SET  TBS22:=TotalBaseStorage;
              SET  BaseDemand:=0.03692*DailyDemand;
{10PM}             ACTIVITY 2;
              SET  TBS24:=TotalBaseStorage;
                 SET TBSLowest:=TIME_MIN(TotalBaseStorage):
                  TBSAv:=TIME_AVE(TotalBaseStorage):
                  TBSMax:=TIME_MAX(TotalBaseStorage):
                  TBSStd:=TIME_STD(TotalBaseStorage);
                  BRANCH FireFlow)0,Fire:
                                  ,Output;

Output
WRITE,OUT1,/:TBSMax,3,0:TBSAv,8,0:TBSLowest,8,0:TBSStd,8,0:

TBS24,8,0:TBS6,8,0:TBS12,8,0:TBS18,8,0; Fire    CLEAR;
              KILL;

              CREATE,1,Control,TimeBetween,TimeBetween;
              ACTIVITY UNIFORM(1,24,3);
              SET FireDemand:=FireFlow;
              ACTIVITY Duration;
              SET FireDemand:=0;
```

91

```
WRITE,OUT1,/:TBSMax,8,0:TBSAv,8,0:TBSLowest,8,0:TBSStd,8,0;
         SET TotalBaseStorage:=NORMAL(2590,675,2);
         KILL;

{Are the tanks full or going empty?}
         MONITOR TotalBaseStorage:
         IF FireDemand)0 THEN;
             SET TBS:=TotalBaseStorage;
         END_IF;
         SET CRCFlow:=(BaseDemand*0.15629)-
(TotalBaseStorage*.03544)+219.16;

         IF TotalBaseStorage)=.95*TotalStorage THEN;
             SET Well1:=OFF:        Well2:=OFF:
                 Well4:=OFF:        Well8:=OFF:
                 Restart1:=ON;
         ELSE;
             IF Restart1=ON THEN;
             SET Well1:=7.1:     Well2:=15.5:
                 Well4:=12.1:    Well8:=11.8:
                 Restart1:=OFF;
             ELSE;
             SET Restart1:=OFF;
             END_IF;
           END_IF;

         IF TotalBaseStorage)=.95*TotalStorage THEN;
             SET Well16:=OFF:       Well17:=OFF:
                 Well111:=OFF:      Well112:=OFF:
                 Well113:=OFF:      Well114:=OFF:
                 Restart2:=ON;
             ELSE;
             IF Restart2=ON THEN;
             SET   Well16:=16.65:    Well17:=17.9:
                   Well111:=15.1:   Well112:=20.7:
                   Well113:=20.9:   Well114:=12.1:
                   Restart2:=OFF;
             ELSE;
             SET Restart2:=OFF;
             END_IF;
         END_IF;

         IF TotalBaseStorage(0 THEN;
           SET TotalBaseStorage:=0;
         END_IF;
         END_MONITOR;

         CREATE,1,Control,1,0;
         SET TBSPlot:=TotalBaseStorage/TotalStorage*10;
```

```
          SCREEN,PLOTQ,0,0,0,10,0;
              CHART,27+MOD(STIME,60),10,1,178,TBSPlot,10;
          SCREEN,PICTURE,0,0,0,12,0;
              SHOW,33,6,WellTotal,5,0;
              SHOW,33,7,BaseDemand,5,0;
              SHOW,33,5,CRCSup,5,0;
              SHOW,52,4,TotalBaseStorage,8,0;
              SHOW,51,13,FireDemand,6,0;
              SHOW,65,13,FutureDemand,6,0;
              SHOW,33,2,Day,3,0;
              SHOW,33,3,TimeOfDay,2,0;
          IF  TimeOfDay>23  THEN;
              SET TimeOfDay:=1:
                  Day:=Day+1;
          ELSE;
              SET TimeOfDay:=TimeOfDay+1;
          END_IF;
          KILL;

          CREATE,1,Control,0.25,0;
              SET CRCSup:=CRCFlow*CRCVlv:

WellTotal:=Well1+Well2+Well4+Well8+Well6+Well7+Wel.11+Well12
+              Well13+Well14:
          TotalRateIn:=WellTotal+CRCSup:
          FutureDemand:=BaseDemand*FuturePercent/100:

TotalRateOut:=BaseDemand+FutureDemand+FireDemand:
TotalBaseStorage:=TotalBaseStorage +0.25*(TotalRateIn -
TotalRateOut);                KILL;

          CREATE,1,Control,RunLength,240,NumRuns;
          CLEAR;
          KILL;

END;  {Discrete section}

CONTINUOUS;
END;
POSTRUN;
              REPORT,'run.out';
              CLEAR;
              BRANCH RunNo=NumRuns,EndRun:
                                   ,ContinueRun;
ContinueRun   KILL;
EndRun        CLOSE,OUT1;
              STOP;
END;
```

93

Appendix B - Model Input Data

Day	CRC Daily Output
1.0000	1840.0
2.0000	1440.0
3.0000	1440.0
4.0000	1430.0
5.0000	1600.0
6.0000	2590.0
7.0000	1740.0
8.0000	1820.0
9.0000	1600.0
10.000	1520.0
11.000	1380.0
12.000	2050.0
13.000	2000.0
14.000	2000.0
15.000	1970.0
16.000	1900.0
17.000	1830.0
18.000	1970.0
19.000	2050.0
20.000	2070.0
21.000	2010.0
22.000	2180.0
23.000	2580.0
24.000	2240.0
25.000	1800.0
26.000	2400.0
27.000	1970.0
28.000	2270.0
29.000	2600.0
30.000	2620.0

Day	Well 1	Well 2	Well 4	Well 8
1.0000	170.00	200.00	460.00	590.00
2.0000	120.00	200.00	550.00	390.00
3.0000	130.00	340.00	240.00	10.000
4.0000	200.00	240.00	330.00	220.00
5.0000	220.00	270.00	300.00	140.00
6.0000	260.00	700.00	460.00	0.0000
7.0000	80.000	250.00	160.00	0.0000
8.0000	280.00	610.00	140.00	370.00
9.0000	20.000	780.00	320.00	0.0000
10.000	90.000	520.00	560.00	0.0000
11.000	200.00	570.00	120.00	380.00
12.000	180.00	0.0000	480.00	630.00
13.000	220.00	420.00	350.00	450.00
14.000	180.00	420.00	410.00	210.00
15.000	180.00	410.00	110.00	490.00
16.000	180.00	180.00	441.00	400.00
17.000	170.00	470.00	320.00	0.0000
18.000	250.00	0.0000	330.00	170.00
19.000	230.00	640.00	370.00	660.00
20.000	180.00	0.0000	140.00	0.0000
21.000	170.00	0.0000	470.00	470.00
22.000	150.00	600.00	280.00	500.00
23.000	120.00	560.00	0.0000	490.00
24.000	190.00	0.0000	170.00	420.00
25.000	60.000	440.00	470.00	0.0000
26.000	140.00	580.00	400.00	420.00
27.000	130.00	640.00	0.0000	210.00
28.000	160.00	0.0000	450.00	560.00
29.000	230.00	590.00	540.00	350.00
30.000	230.00	590.00	540.00	0.0000

Day	well 6	Well 7	Well 11
1.0000	530.00	430.00	360.00
2.0000	360.00	400.00	390.00
3.0000	390.00	410.00	380.00
4.0000	460.00	460.00	380.00
5.0000	500.00	540.00	420.00
6.000	340.00	400.00	290.00
7. 00	430.00	440.00	360.00
.0000	450.00	360.00	360.00
9.0000	340.00	460.00	380.00
10.000	410.00	500.00	340.00
11.000	420.00	380.00	380.00
12.000	410.00	420.00	390.00
13.000	360.00	400.00	350.00
14.000	450.00	490.00	370.00
15.000	430.00	480.00	380.00
16.000	370.00	400.00	330.00
17.000	400.00	420.00	390.00
18.000	300.00	470.00	320.00
19.000	400.00	440.00	370.00
20.000	400.00	460.00	350.00
21.000	380.00	410.00	380.00
22.000	430.00	390.00	320.00
23.000	370.00	400.00	370.00
24.000	430.00	410.00	350.00
25.000	330.00	400.00	360.00
26.000	430.00	430.00	350.00
27.000	360.00	420.00	370.00
28.000	370.00	440.00	370.00
29.000	370.00	460.00	360.00
30.000	370.00	400.00	360.00

Day	TBS24	TBS2	TBS4	TBS6
1.0000	3198.0	3476.0	3698.0	3790.0
2.0000	2950.0	3262.0	3500.0	3738.0
3.0000	2924.0	3220.0	3428.0	3638.0
4.0000	3168.0	3416.0	3634.0	3638.0
5.0000	3127.0	3372.0	3480.0	3610.0
6.0000	2700.0	2919.0	3018.0	3276.0
7.0000	2395.0	2768.0	2962.0	3316.0
8.0000	2850.0	3150.0	3310.0	3490.0
9.0000	2198.0	2640.0	2946.0	3144.0
10.000	2286.0	2648.0	2922.0	3076.0
11.000	2226.0	2624.0	3009.0	3240.0
12.000	2782.0	2932.0	3207.0	3292.0
13.000	1778.0	2086.0	2284.0	2398.0
14.000	1864.0	2122.0	2428.0	2722.0
15.000	1719.0	2160.0	2490.0	2670.0
16.000	1740.0	2244.0	2584.0	2868.0
17.000	1466.0	2100.0	2396.0	2818.0
18.000	1854.0	2124.0	2374.0	2580.0
19.000	1516.0	1860.0	2379.0	2510.0
20.000	1192.0	1623.0	1784.0	2282.0
21.000	1244.0	1628.0	1978.0	2340.0
22.000	1384.0	1620.0	1920.0	2233.0
23.000	1658.0	2114.0	2388.0	2638.0
24.000	2096.0	2568.0	2600.0	2906.0
25.000	2913.0	3118.0	3366.0	4037.0
26.000	2236.0	2752.0	2922.0	3188.0
27.000	2166.0	2497.0	2824.0	2922.0
28.000	1896.0	2440.0	2630.0	2948.0
29.000	2218.0	2510.0	2940.0	3178.0
30.000	2320.0	2644.0	2950.0	3266.0

Day	TBS8	TBS10	TBS12	TBS14
1.0000	3700.0	3660.0	3554.0	3486.0
2.0000	3722.0	3668.0	3566.0	3510.0
3.0000	4083.0	4054.0	3756.0	3796.0
4.0000	3700.0	3780.0	3754.0	3766.0
5.0000	3532.0	3564.0	3500.0	3424.0
6.0000	3280.0	2900.0	3148.0	3140.0
7.0000	3250.0	3032.0	3107.0	3225.0
8.0000	3240.0	3150.0	2992.0	2918.0
9.0000	3131.0	2976.0	3015.0	2968.0
10.000	3318.0	3162.0	3220.0	3172.0
11.000	3448.0	3366.0	3294.0	3292.0
12.000	3484.0	3413.0	3225.0	3050.0
13.000	2430.0	2534.0	2576.0	2560.0
14.000	2582.0	2853.0	2862.0	2868.0
15.000	2816.0	2921.0	2892.0	2846.0
16.000	2700.0	2456.0	2644.0	2626.0
17.000	2681.0	2647.0	2805.0	2601.0
18.000	2582.0	2796.0	2678.0	2654.0
19.000	2428.0	2314.0	2086.0	2080.0
20.000	2204.0	2220.0	2200.0	2186.0
21.000	2394.0	2312.0	2074.0	2092.0
22.000	2144.0	1988.0	1716.0	1546.0
23.000	2538.0	2412.0	2276.0	2182.0
24.000	2800.0	2576.0	2534.0	2506.0
25.000	3320.0	3304.0	3236.0	3220.0
26.000	3168.0	3028.0	2780.0	2632.0
27.000	2870.0	2584.0	2770.0	2680.0
28.000	2784.0	2600.0	2452.0	2656.0
29.000	3152.0	2848.0	2998.0	2668.0
30.000	3166.0	2906.0	2704.0	2706.0

Day	TBS16	TBS18	TBS20	TBS22
1.0000	3450.0	3424.0	2636.0	2438.0
2.0000	3330.0	3333.0	2964.0	2758.0
3.0000	3754.0	3546.0	2734.0	2664.0
4.0000	3744.0	3684.0	2940.0	2838.0
5.0000	3374.0	3250.0	2676.0	2264.0
6.0000	3118.0	3040.0	2372.0	1974.0
7.0000	3164.0	3014.0	2700.0	2400.0
8.0000	2778.0	2818.0	2164.0	1750.0
9.0000	2782.0	2760.0	2400.0	2260.0
10.000	2914.0	2840.0	2292.0	1908.0
11.000	3212.0	3024.0	2580.0	2380.0
12.000	2896.0	2789.0	2112.0	1640.0
13.000	2570.0	2080.0	1750.0	1270.0
14.000	2770.0	2700.0	1874.0	1456.0
15.000	2730.0	2420.0	1972.0	1508.0
16.000	2506.0	1898.0	1724.0	1380.0
17.000	2660.0	2530.0	1860.0	1470.0
18.000	2708.0	2312.0	1808.0	1286.0
19.000	1974.0	1842.0	1426.0	978.00
20.000	2170.0	1810.0	1492.0	1142.0
21.000	2028.0	1932.0	1332.0	942.00
22.000	1606.0	1556.0	1280.0	1420.0
23.000	2232.0	2112.0	2048.0	1960.0
24.000	2532.0	2826.0	2796.0	2752.0
25.000	3098.0	3098.0	2458.0	2054.0
26.000	2676.0	2262.0	2124.0	2118.0
27.000	2604.0	2480.0	2016.0	1710.0
28.000	2710.0	2522.0	2178.0	1808.0
29.000	2780.0	2518.0	2780.0	2072.0
30.000	2306.0	2216.0	2270.0	2060.0

HISTOGRAM OF DAYTOT

LOW	N	HIGH	(X 10^3)
4.2		4.6	
	1		
4.6		5.0	
	3		
5.0		5.4	
	6		
5.4		5.8	
	10		
5.8		6.2	
	5		
6.2		6.6	
	4		
6.6		7.0	
	1		

Figure 13.   Daily Total Probability Distribution

Test Parameters

Mean	5.605	Critical value	.242
Std Dev	.582	Test Statistic	.053
Sample Size	30		
Level of Significance	0.050	Accept Hypothesis	

Appendix D — Abbreviations and Conversions

af: Acre-Feet
cf: cubic feet
cfs: cubic feet per second
CRC: Colorado River Commission
gpm: gallons per minute
kwh: kilowatt per hour
mg: million gallons
mgd: million gallon per day
SNWS: Southern Nevada Water System
tdh: total dynamic head

Conversions

1 acre-feet	=	43,560	cubic feet
1 acre-feet	=	.3259	million gallons
1 cubic foot per second	=	448.831	gallons per minute
1 gallon per minute =		.002228	cubic feet per second
million gallons per day	=	694.444	gallons per minute

Bibliography

Campbell, Thomas C., "Water: Allocating a Scarce Resource," _Journal of the American Water Works Association._ 75:53-56 (September 1985).

Clock, Gene, Nevada Department of Water Resources official - wells department. Carson City NV, 11 Jul 89.

Cobbin, Philip, SIMPLE_1 - An Integrated Simulation Environment. Reference Manual. (Sierra Simulations & Software, Campbell CA. 1989)

Davis, Allen L. and Roland W. Jeppson, "Developing a Computer Program for Distribution System Analysis," _Journal of the American Water Works Association._ 79:236-241 (May 1979).

Dorsey, Bud, Nellis utilities engineer. Telephone interview. Nellis AFB NV 89110, 4 Aug 89.

Edwards, Jerry, Chief Engineer for the Colorado River Commission. Telephone interview. Las Vegas NV, 2 Aug 89.

Ellis, Major General George E., "In Search of a Better Eagle's Nest," _Air Force Journal of Logistics._ 11:7-10 (Summer 1986).

Emory, C. William, _Business Research Methods._ (Homewood, Illinois: Richard D. Irwin Inc. 1985).

Emshoff, James R. and Roger L. Sisson, _Design and Use of Computer Simulation Models._ (New York: Macmillan Publishing, 1970).

Graeser, Henry J., "The Specter of Cities Without Water," _Journal of the American Water Works Association._ 75:14,102 (September 1985).

Grasso, John, System operator for the Las Vegas Valley Water District. Telephone interview. Las Vegas NV, 11 Jul 89.

IMS, "Allocating Water Supplies," _Journal of the American Water Works Association._ 75:33 (September 1985).

Keller, First Lieutenant F. Susan, Programming engineer at Nellis. Telephone interview, 12 Jun 89.

Kleijnen, Jack P. C., <u>Statistical Techniques in Simulation</u>. (New York: Marcel Dekker, 1974).

Litko, Major Joe, Operations Research instructor. Classnotes from Logistics Simulation, 1989.

Mckinney, Dave, Real Property Technician, Real Property Branch, Telephone interview. Bolling AFB, 28 Mar 89.

O'Dell, Ray, Retired Water and Waste Superintendant at Nellis AFB, Personal and telephone interviews.

Pritsker, A. Alan B., <u>Introduction to Simulation and SLAM II</u>. (New York: Halsted Press 1986).

Rodewick, Robert, Nellis water superintendant. Telephone interview. Nellis AFB, NV 89110.   28 Jul 89.

Sargent, Robert G., "A Tutorial on Validation and Verification of Simulation Models," <u>Proceedings of the 1988 Winter Simulation Conference</u>.   :33-39 (Winter 1988).

Thornton, William J., "Our Nation's Infrastructure: Not Making the Grade," <u>The Military Engineer</u>. 79:580-583 (November-December 1987).

U.S. Department of the Air Force. <u>Water Supply, Water Storage</u>. AFM 88-10, Chptr 4.

U.S. Department of the Air Force. <u>Water Supply for Fire Fighting</u>. AFM 88-10, Chptr 6.

Upmeyer, David W. P.E., "Estimating Water Storage Requirements," <u>Public Works</u>. 45:50-54 (July 1978).

URS, "Hydraulic Analysis of the Nellis AFB Water Distribution System," Architect/Engineer's report, URS, Las Vegas, NV, (1985).

Walski, Thomas M., "Using Water Distribution System Models," <u>Journal of the American Water Works Association</u>. 74:58-63 (February 1983).

Wilkinson, Charles F., "Western Water Law in Transition," <u>Journal of the American Water Works Association</u>. 74:34-47 (October 1986).

Captain Stephen D. Grumbach ███████████████

███████████████████████████ He graduated from

Summerville High School in 1980 and attended Clemson

University. Upon graduation from Clemson with a Bachelor of

Science degree in Mechanical Engineering, he was

commissioned through ROTC in May 1984. His first assignment

was with the 554th Civil Engineering Support Squadron at

Nellis AFB, Nevada. Captain Grumbach worked initially as a

mechanical design engineer within Technical Design.

Subsequently, he moved on to hold the positions of utilities

engineer, Deputy Chief of Operations, and Chief of Resources

and Requirements. He entered the School of Systems and

Logistics, Air Force Institute of Technology, in June 1988.

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE		Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS

2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Aprroved for public release; distribution unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	

4. PERFORMING ORGANIZATION REPORT NUMBER(S) AFIT/GEM/ENS/89S-9	5. MONITORING ORGANIZATION REPORT NUMBER(S)

6a. NAME OF PERFORMING ORGANIZATION School of Systems and Logistics	6b. OFFICE SYMBOL (If applicable) AFIT/LSM	7a. NAME OF MONITORING ORGANIZATION

6c. ADDRESS (City, State, and ZIP Code) Air Force Institute of Technology Wright-Patterson AFB OH 45433-6583	7b. ADDRESS (City, State, and ZIP Code)

8a. NAME OF FUNDING/SPONSORING ORGANIZATION	8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER

8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS			
	PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO	WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)

See Box 19

12. PERSONAL AUTHOR(S)
Stephen D. Grumbach, B.S., Captain, USAF

13a. TYPE OF REPORT Thesis	13b. TIME COVERED FROM _____ TO _____	14. DATE OF REPORT (Year, Month, Day) 1989 September	15. PAGE COUNT 116

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Water Simulation; Water Resources; Water Distribution; Water Supplies; Simulation
13	02		

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Title: A Case Study of the Water Supply System at Nellis Air Force Base Using Computer Simulation

Faculty Advisor: Thomas F. Schuppe, Lt Col, USAF
                   Professor, Operations Research

Approved for public release: IAW AFR 190-1.

LARRY W. EMMELHAINZ, Lt Col, USAF   11 Oct 89
Director of Research and Consultation
Air Force Institute of Technology (AU)
Wright-Patterson AFB OH 45433-6583

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL Thomas F. Schuppe, Lt Col, USAF	22b. TELEPHONE (Include Area Code) (513) 255-2549	22c. OFFICE SYMBOL AFIT/ENS

DD Form 1473, JUN 86   Previous editions are obsolete.   SECURITY CLASSIFICATION OF THIS PAGE

Unclassified

Abstract

The water supply system of a military installation is an
integral part of the utility infrastructure and critical to
the mission of the base. The system must be prepared to
handle domestic, industrial, fire-fighting and chemical
decontamination requirements in a reliable manner.

The purpose of this study was to examine, tnrough the use
of standard techniques and computer modeling, the current
and future supplies and demands of the water utility system
at Nellis AFB, Las Vegas, Nevada. The desired macroscopic
perspective suggested the use of accurate statistical and
simulation techniques. A general approach was taken so that
the procedure is applicable to other Air Force water systems
as well.

Based on historical data, current operating conditions
and projected demands, the Nellis water system is at a
critical point if the base management is concerned about
safety as well as future expansion. Current ability to
fight a fire for extended periods is suspect. Current and
future storage needs do not fit Air Force guidance and are
far below civilian requirements. Future construction plans
will significantly increase demands on the system. To
account for these increased demands, supplies must be
increased as well. Unfortunately, there are few new sources
and the costs will increase dramatically.

The simulation model provided a tool for the analysis of
water systems and could be useful in future utility
analysis.

Unclassified